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EXPOSITION

OF THE

PRINCIPLES

OF

ABBOTT'S HYDRAULIC ENGINE,

WITH TABLES & ENGRAVINGS:

Together with

AN ILLUSTRATION OF THE POWER OF WHEELS,

HERETOFORE USED.

BY JOHN ABBOTT,
South Reading, Mass.

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PREFACE.

In preparing the following work for publication, the author has been induced, from several considerations, to extend it much farther than was originally anticipated. At first it was thought that all the necessary information respecting the Hydraulick Engine, might be given on a single sheet: finding that impossible, I have ventured to go more into detail than was designed—have made quotations, and selected many Tables, from other authors, in addition to my own, believing they will be found very useful to most mechanicks, as the work may come within the means of all; thus obviating a difficulty which has hitherto existed—as almost all treatises upon the laws of practical mechanics now extant, are extremely expensive.

J. A.

In submitting my improved Water Power to the public, I have prepared a number of Engravings, to show the several modes I have designed for its application. The principles upon which this improvement is founded, are those of applying the weight of water, in a vessel or vessels, descending in a vertical line from the top to the bottom of the fall, and to communicate motion to the mill by the several modes delineated in the annexed engravings. When it is considered that there is no power in water, independent of its weight, it will appear very evident, that when applied in a vertical direction, it must produce the greatest possible effect of which it is capable;—and if the engines in which I purpose using water, in such manner, are rightly constructed, not a particle can escape, or fail to produce the desired effect.

If we can rely upon the testimony of Messrs. Oliver Evans, John Smeaton, Thomas Fenwick, Fergerson and many other celebrated authors on practical mechanicks, we can readily account for the general complaint of a scarcity of water in dry seasons, and its baneful effects. These authors, particularly Evans and Smeaton, were of opinion that the ratio of power derived from a given quantity of water,—when applied to different wheels, under similar circumstances, was nearly as follows. Out of every 100 pounds of water discharged upon an over shot wheel, is derived a power of 68 pounds, or 68 per cent. From the same quantity when applied to the Breast wheel 52 per cent. Under shot wheels 34 per cent. Tub wheels 25 per cent. And it has been found by some experiments on the reacting wheels, that they do not obtain more than 10 per cent of the water used.

We shall be very far from considering the power of these wheels underrated when we compare it with other remarks and established rules laid down by the same authors, especially the three wheels last mentioned.

Thomas Fenwick fixes the power sufficient to grind 6 bushels of corn per hour, (with a five feet stone) equal to a vessel containing 375 pounds of water, if applied in a manner as described in Plate No. 3 of the Engravings; which power will give the mill stone 100 revolutions per minute, grind the corn and descend about 3 1-2 feet per second, or 200 feet per minute; which, for mills intended to be moved in a manner described in the annexed engravings, or by the gravity of water is found by careful observation to produce the greatest mechanical effect possible, where time is regarded; or if 575 pounds be applied in the same manner it will grind 12 bushels of corn to the hour, and so on. To give the mechanic a full and perfect understanding of this matter, if there be but 10 feet fall it would require 20 discharges of the vessel per minute, because it could be used but 1 20th of the 200 feet (descent or velocity) and would consume 5 tons, 1500 pounds per minute; or if there were 50 feet fall it would require but 4 discharges, and consequently would use but 1 ton, 300 pounds per minute. Besides, if the same labor (namely, 12 bushels ground per hour) were required of an undershot wheel, it appears from a certain table laid down in Mr. Evans' "Young Millwright and Miller's Guide," page 154, it would require 43 tons, 250 lbs. per minute; or if required of a tub wheel, then it would take 46 tons, 1150 pounds of water per minute, as appears from page 158.

By these remarks it will be seen that not more than 12 per cent. of power is derived from the water used.

As for re-acting wheels I deem it unnecessary to enter into any details about them,—suffice it to say they consume much water and are but little used.—They are very good wheels however, when the miller has more water than he can conveniently discharge through his waste gates. I have hitherto been unable to ascertain exactly the amount of power required for saw mills, but from what I have been able to gather from millwrights, and from my own experience, the power for saw mills does not vary much from that of grist mills. The water however for the former is not generally so well applied as for the latter, as will appear from Mr. Evans' book, page 343, where he requires for a single saw, a gate to be drawn under a 10 feet head of such dimensions as will discharge 60 tons of water per minute; whereas if there was no loss 5 tons, 1500 pounds would be sufficient. I might cite numerous cases to prove the truth of the foregoing remarks, but think enough has been said to satisfy every candid reader, that the ratio of power derived from a given quantity of water, when applied to different wheels, as laid down by Messrs. Evans, Smeaton and others, is very far from being underrated. In fact I doubt whether there is more than one wheel in twenty of the three last mentioned wheels that derive more than 12 per cent. of the power of the water used. The two first mentioned wheels are very good ones, and their superior merits to the other wheels have long been tested.—These wheels however can seldom improve a fall of more than 30 feet, because when made large they become unwieldy, and take up much room, are exposed to ice in the winter season, and are very expensive. I do not undertake to vouch for the correctness of the theories of those authors, from whom I have made quotations, but think them fraught with a great degree of accuracy. But to put this question beyond all doubt, I will here insert the rule by which the power of wheels is known, so that every miller may; at his leisure satisfy himself as to the truth of the preceding remarks.

Rule.—Attach a rope to the periphery of the water wheel or to the end of a lever, in length equal to the radius of the wheel, being attached to the shaft, passing it over a single pulley at a right angle with the lever or point of the wheel; then suspend such a weight as will cause the wheel and weight to be held in an equilibrium, when the gate is fully drawn,—then take off the weight and ascertain the distance the periphery of the wheel moves in a minute, if it move at the rate of 4 feet per second, then subtract 4 16ths of the weight, and the remainder will be the weight hoisted, the distance through which the periphery moved per minute, or the amount of power. If it be 8 feet per second, then 8 16ths should be subtracted, and the same proportion for a greater or less velocity, and by the same rule may be known how to charge or load a wheel so as to give it any velocity less than 16 feet per second. Then by comparing the area of the gate with the Table No. 1, the amount of water discharged per minute will be found. To make this more plain, for an example—suppose we draw a gate of 1 foot square, under a 25 feet head, upon a wheel, and a rope be attached as described in the rule, and a given weight, suppose 1600 pounds, to be held in an equilibrium; I then take off the weight, and find the periphery of the wheel to move 360 feet per minute, or 6 feet per second; I then subtract 6 16ths as being spent in giving velocity, (for if there were no motion, there would be no mechanical effect,) which will leave 1000 pounds raised 360 feet per minute, which we call the power of the wheel; Then if there be a wish to know how much water has been spent to perform this labor; compare the area of the gate with Table No. 1, and it will be found to be 153,216 pounds; that is, 153,216 pounds have descended 25 feet (I say descended, because it makes no difference whether it falls 25 feet or issues from under a 25 feet head, the effect is the same) to raise 1000 pounds 360 feet. Again, suppose a merchant, wishing to raise a bale of goods, weighing 1 ton, into a loft 25 feet from the ground or street, in which loft he has a fountain or reservoir of water, and by means of a rope made fast to the goods, passing it over a single pulley, and attached to a vessel into which he intends to admit water to raise the goods; now, under these circumstances, it would require but a fraction more than a ton to do the work; but if he apply the water by its impulse, or to some Engine, in which it would require some 10 or 12 tons, to perform the labor, it would look as much like a waste of water or loss of power, as any thing imaginable. Many people, not thorougly acquainted with the principles of hydraulics, entertain an opinion, that water issuing from a fountain, has a greater power or superior force to its gravity; for say they, "how swift it runs." But it should be remembered that the effect can never be greater than the cause, or the servant greater than his master;—it is gravity alone that gives motion, and that motion or quantity discharged will always be in proportion to the head or weight of water above the aperture in the fountain. Even our yeomanry, if they carefully examine, will find that the hole or aperture in their cider barrel, was no larger when they could draw a quart in a minute, than when it required five minutes; they will only find that the barrel is almost empty, and if they but rap on it, it would say to them, Economy! Economy! Prudence—Temperance. Perhaps my principle of using liquids, may be applied morally, as well as mechanically. The specification for the former would simply be, draw from the surface through a little hole, and use it with *gravity*. The only power or force in water of which I have any knowledge, is that of its weight or gravity, which would forever keep it in a state of rest, if it were not acted upon by some other power, or placed in a moving position—for instance: on an inclined plain, upon which stone or any other matter, if made in a globular form, like the particles of water, would have the same motion, and be governed by the same laws. As to the utility of using water by impulse or gravity, it need only be said that spouting fluids spend half their gravity in changing their form, and of course can produce but half the mechanical effect. It has been my endeavor, in the preceding remarks, to show in as plain a manner as possible, that water used by its gravity (instead of impulse) is far the best method of applying it; and for the Wheel, Engine, or Machine, in which can be retained the greatest portion of the gravity of the water used, I shall leave for the public to judge. But few millers are aware of the immense weight of water made use of for ordinary mechanical purposes; as for instance, a grist mill, which will almost imperceptibly exhaust a fountain of water, equal to a canal 1 mile in length, 10 feet wide and 10 feet deep. Yet this canal contains no less than 16,500 tons of water, which if applied to a fall 100 feet, (which frequently occur in hilly countries,) in the manner the merchant applied water to raise the goods, (making no allowance for friction) would raise 16,500 tons 100 feet, or 1000 pounds to the enormous height of 625 miles; and still this reservoir of water, dwindles into insignificance, when compared with the fountains at the command of most millers. Notwithstanding the vast magazines of power which our well watered country affords, the complaint is almost universal, that scarcity of water is prevalent in some seasons of the year; large manufacturing establishments are suspended—the manufacturer's business is deranged—his customers disappointed, and hundreds of people dependent on their labor for support, are turned out of employment. And even many of our corn mills are unable to supply the inhabitants with stock for bread. In this state of things, people seem to have been more in the habit of praying for rain, than in showing gratitude for what they had, by studying economy in the application of it; forgetting perhaps "That God giveth rain upon the earth, and sendeth waters upon the fields." At least it can be presumed that with two thirds of the surface of the earth covered with water, there should be enough to grind the corn; if it be not done, the words of Pope should be remembered:

> "*If vain our toil—we ought to blame the culture, not the soil.*"

There is one thing more that claims a consideration, which I shall here briefly notice, and then close the subject with a few explanatory remarks on the different modes of applying this improved principle, which I claim, as the inventor, as shown in the annexed engravings. Owing to the immense quantity of water made use of by some of the present modes of application, millers are under the necessity of locating their mills on large streams, liable at one season of the year to be rendered useless by a drought, and at another to total destruction, by an inundation; and to secure a plenty of water and apply it to use, large dams, expensive wheel-pits, raceways, flooms and canals must be built and supported, and the location of them is frequently attended with much trouble and inconvenience. To obviate some of the troubles heretofore enumerated, I now present to the public (by sale) a new and improved principle, and mode of applying water for mechanical purposes. The fundamental part of this improvement, is that of using water by its gravity, in a vertical direction. For a more complete understanding, reference may be had to the engravings, and the specification accompanying the Grant, from the Government of the United States, which secures to the inventer and improver the exclusive privilege of using said improvement, and vending the same to others, for the term of fourteen years from the date thereof, according to an Act of Congress. The Author having erected a mill the past year on this plan, and introduced an Engine of about five horse power, thinks he has had a sufficient opportunity to test the principles and judge of its utility. The following is a certificate very respectfully handed me by Mr. James C. Nichols, of Reading, Mass. a gentleman of much experience and of high standing as a mechanic and machinist, both in science and practice.

READING, FEB. 1835.

To whom it may concern.—Having been recently employed in the construction of Mr. John Abbott's Improved Vertical Water Engine, I have had full opportunity of comparing it with all the other modes for obtaining water power within my knowledge, and give it as my opinion, that the power (from a given quantity of water) and facility of application for propelling different Machines, Mills &c. it has never been surpassed. The comparatively small quantity of water requisite, (especially where a great fall can be obtained) together with the small difference in the expense of constructing for a greater or less fall are considerations which will render valuable many small streams which for any ordinary mode would be useless. The cheapness and density of this Engine, the little expense of daming and canalling, and the consequent convenience of locating mills, added to the above considerations, render it in point of economy superior to any mode I have ever known.

JAMES C. NICHOLS, *Millwright and Machinist.*

The Mill referred to in the foregoing certificate is situated in the south east part of Reading, Mass.—In the erection of this mill, we had to encounter some of those troubles more or less common to all mill sites, ledges, quick-sands, &c. To give the reader a general understanding of some of the benefits to be derived from this mode of application, I will very briefly give a description of this mill, and its location. This mill is situated on a small stream, with a descent of about 20 feet in the distance of 12 rods. As the stream is subject to a drought,* it was deemed expedient to raise a pond, and for that purpose a dam was erected, about 6 feet high, at the top or begining of the decent, to fill a small valley above with water. The mill is located about † half way down the descent, where a pit of 4 1-2 feet square is sunk to the depth of 10 feet, ‡ from which the water is carried out in an aqueduct, 200 feet to the fields below.

The water is taken from the pond by a wooden pipe of 7 inches diameter, and carried into the basement story of the building, where an iron pipe of 6 inches diameter is inserted into the wooden one, in which the water rises perpendicularly, till it comes within about six feet of being as high as the water in the pond or fountain, where it is admitted into the Engine through an aperture of 2 1-2 inches square; thus situated, we have about 6 feet head, 20 feet fall, and the *aperture or gate* is 2 1-2 inches square, and the power derived from the water issuing from the *aperture* under the circumstances above named, is judged by good mill wrights to be sufficient to carry a grist mill, with a 5 feet stone, and to grind about 12 bushels of corn per hour. This power, however, is applied to other mechanical purposes.

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* If there had been a stream sufficient during the whole season to have supplied the pipe or engine, the dam might have been dispensed with.

† If the mill had been built at the top or the bottom of the fall, so as to have improved the whole of it as it now does, an expensive dam in the one case, or an extensive and deep excavation for a raceway in the other, would have been the result. In sinking the pit, we come to a ledge of rocks; but the small compass which this pit occupied rendered the expense not more than one tenth part of what would have been required for other wheels.

‡ In the raceway below the mill, a considerable part of the way, was a bed of quicksands, which would have been very troublesome in case of a wall or open raceway; but the small quantity of water which the mill required, made it very convenient to carry it out in an aqueduct; this aqueduct was put down in joints, beginning at the lower end, and after laying down one joint, the sand that was taken for a place for the second joint, was used to cover up the first joint, and in this way the whole was laid down. Perhaps, it would be well to remark, that the lower end of the pipe descends a little below the surface of the water, at the outlet, so as completely to exclude the external air from the wheel pit.

From what has been shown, I think it must be seen, and will be conceded, that this Engine has properties, and possesses advantages, that can never be derived from any of the wheels at present in use; and although a vibratory motion in all machinery is objectionable, yet in this case, when the benefits and advantages are compared, it dwindles into insignificance. Some of the advantages particularly worthy of notice, are, 1st, no fall of water can be too great to be improved by this Engine, and the additional expense for one of 100, over that of 25 feet, is very trifling. 2dly, however small the stream or quantity of water, there can be no waste, nor any portion of it fail of producing its desired effect; and in this way thousands of streams may be brought into use, which at present are considered of no value, and unworthy of notice. 3dly, The small compass which this machine occupies, the expensive wheel pits commonly required, are reduced to a mere trifle.

Flooms in all cases may be dispensed with, and where there is a sufficient run of water to supply the Engine or aquaduct, the season through, dams and ponds are useless. The water may be brought to the mill, and carried away from it, in aquaducts, so that the miller may locate his mill near his dwelling house, for his better convenience, and remote from the stream, to avoid destruction by inundations. These Engines may be attached to any machinery, but with less trouble, however, to some, than to others; and if faithfully made or constructed, are not more liable to get out of order than any other machine, composed of the same number of parts. In the construction of them, simplicity and good workmanship are recommended, and should in all cases be strictly observed. As to the power of these Engines, when a given quantity of water is applied to them, it need only be said, they receive the full weight and gravity of the water so applied; which is all the power of water, of which I have any knowledge; and if the wheels commonly used, lose nothing, then this Engine can gain nothing; but this fact is so well known, that it needs no illustration. I have several methods of applying this principle to practice, some of which are described by the engravings, and the mechanic should be very careful to select that method which is particularly adapted to the situation where the Engine is wanted. These Engines may be used with good success in most situations, but are more especially designed for considerable falls of water. One method, however, may be very successfully applied in low heads. and in tide water. A better description of them will be found on the pages of reference connected with the engravings. I have prepared and selected several tables, to accompany this work, which I trust will be found very useful in the construction of these Engines, and in water works generally; and also to mechanics of most branches. It was with much trouble and expense that the tables No. 1 and 2 were made; having nothing but actual experiment to obtain the principle by which they are calculated; and in carrying out the principle to the length which I have, it is presumed that perfection in every point will not be expected; but I have endeavored to arrange them so as to have them hold good in practice, particularly the second table; by table No. 1, the mechanic or miller will be enabled to ascertain with a tolerable degree of accuracy, the quantity of water in pounds, required to carry a mill by the present modes of using water, some allowance should be made for what the wheel will retard the water. To apply this table;—in the first column will be found the head of water above the gate or aperture; in the top line will be found the size of the gate in inches square; having found the area of any gate, find that number in the top line which contains the same inches, or that which comes the nearest (if the table does not contain it, then it may be found by doubling that number which contains half of it) trace the column underneath, down till you come to the line against which stands the head of water in feet; and at a right angle with these two numbers will be found the weight of water discharged per minute. By table No. 2, the area of a gate under one foot head* will be found sufficient to discharge a quantity of water capable of producing different powers, from one to one hundred horse power, under different falls from 9 to 100 feet. A horse power is here considered 165 pounds of disposable weight, moving with a velocity of 200 feet per minute, and allowing 35 pounds to be spent in giving such velocity and overcoming the friction; or, if time be not regarded, a horse power contains a pressure of 200 pounds on the piston or vessel; if the water be brought to a mill in an aqueduct, the pipe should be somewhat larger than the area of the gate, also, some allowance should be made for the friction of the aperture or gate. This table of horses power is calculated from Messrs. Boulton and Watt, who rate the power of a horse to be equal to 33,000 pounds moving 1 foot per minute. The application of this table is similar to table

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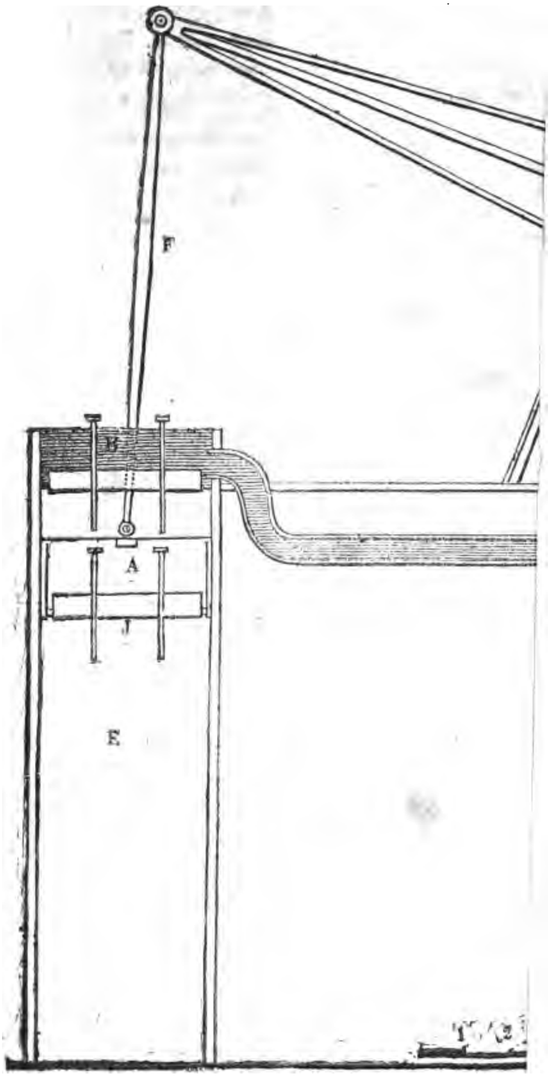
*If the head be 4 feet, then it would require an aperture or gate of but half the size.

No. 1,—in the top will be found the horses power, and in the first column, the fall, &c. &c. As there is a great diversity of opinion among mechanics respecting the power of horses necessary to produce certain mechanical effects, I have thought proper to insert another table,—corresponding with table No. 2, as to horse powers, but given in weight where time is not regarded; and also the disposable force or constant pressure, when moving with a velocity of 200 feet per minute, agreeably to said table. The engravings are made on a scale of one fourth of an inch to a foot; and the proportion of their several parts may be varied to circumstances, at the discretion of the machinist. The valves should be made large, so as to admit the water into the vessels instantaneously; and their proportion may be found by the area of the gate or aperture, and should be to the gate, as 60 is to 1, when under the same head. I have found by practice that the best method of making valves, is that of dropping them into an orifice, like a wedge; but the angles should be made so as by no means to pinch;—this will be found the most simple, the most durable, and to discharge the water the best.

Explanation of Figure No. 1.—By the method of applying to practice the principles of this Engine, as represented in the above engraving, Fig. 1, water may be used under any fall from 9 to 20 feet, with two buckets; but if there be a greater fall, it may be improved with a beam, by adding 2 or more buckets, and also 2 or more cisterns; so that the upper buckets may discharge their contents into the next cisterns below; and the next tier of buckets will receive the water and carry it down to a third tier of cisterns if required, and so on; then by connecting the several buckets together, and the upper buckets being attached to a beam, water may be advantageously worked under any fall whatever. By placing 2 or more beams on the same shaft, the buckets may be made of any length, and of sufficient capacity to contain any quantity of water required, and for any power necessary. The motion may be communicated by an elliptical circular rack, as is shown above; or by the common or bell crank. The beam may vibrate above or below the buckets as convenience shall dictate; or it may be suspended so as to vibrate like the pendulum of a clock, raising and lowering the buckets, by chains passing over pulleys.

1. A A Buckets.
B B Cistern.
C Aqueduct.
D Gate.
E E Pits.
F F Connecting Rods.
G Beam.
H Eliptical Circular Rack.
I Fly Wheel.
J Valves.

PLA

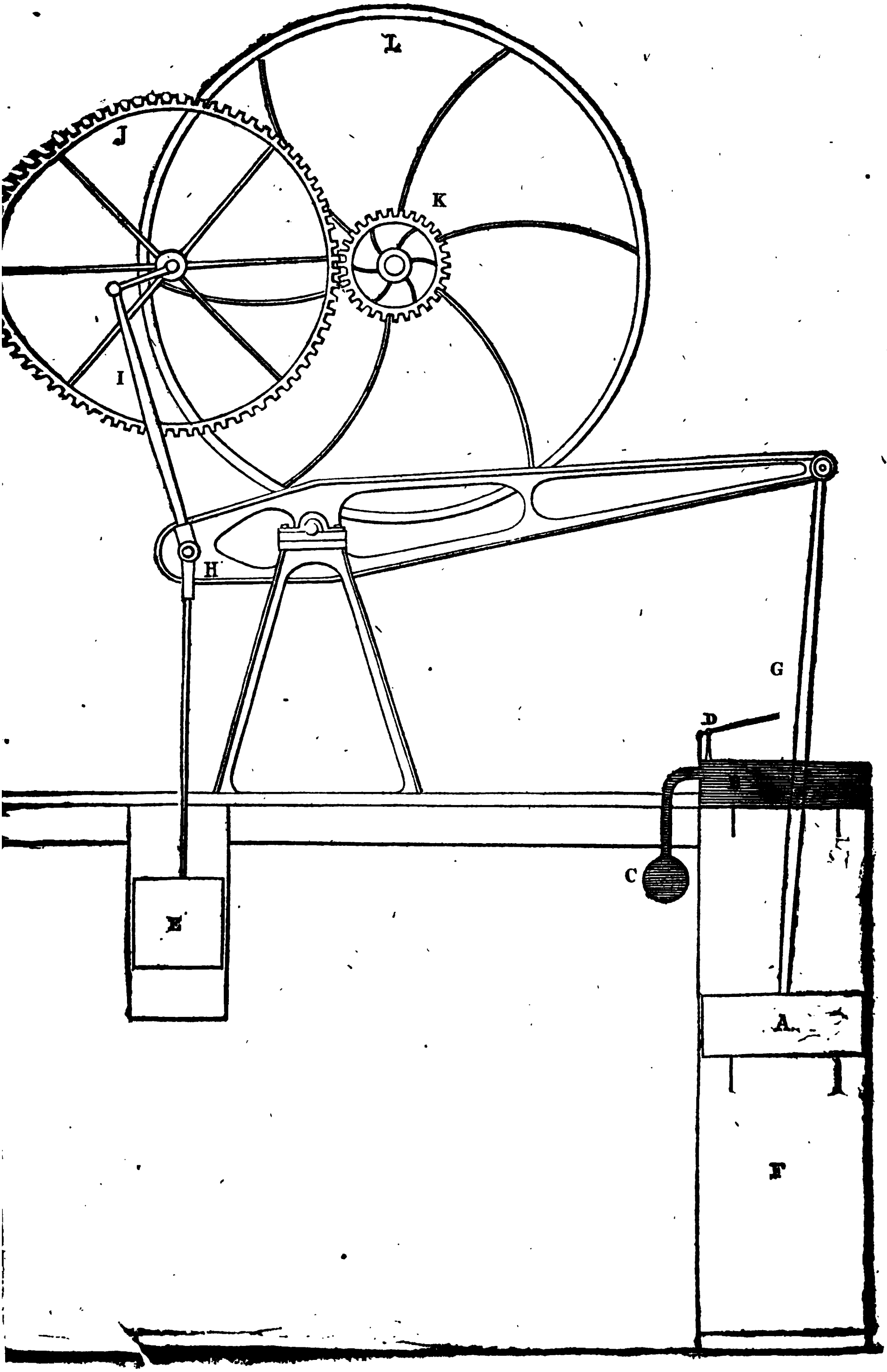


Explanation of Figure No. 2.—The mode of applying the same principle as is described above, Fig. 2, is particularly designed for situations where there is not room for a double lever or beam—where the site of the building requires the location of the Engine to be made in that part where ledges of rocks would render it inconvenient to sink a pit. In this form of an Engine the water is all admitted into one bucket, and at one end of the lever: a weight is suspended at the other end, and that weight should be but half the weight of the water in the bucket, so that when the water is discharged from the bucket, it acts for power.

It should be understood that the power is equal only to half the water in the bucket, or the counter weight; this is calculated to be carried out to any extent with that of Fig. 1, by adding more buckets, cisterns, beams &c. Two or more of these Engines may be brought to bear upon the same shaft; if there are but two, their cranks should be placed on a line with one opposite to the other; if there be three they should be placed at angles of 120 degrees; if four at angles of 90 degrees; so that some one of them may be in that part of its orbit where it would have the greatest pressure, while others were discharging or filling.

2. A Bucket.
B Cistern.
C Aqueduct.
D Gate or Stop-cock.
E Returning Weight.
F Pit or Trunk.
G Connecting Rod.
H Beam.
I Crank Rod.
J Spur Gear.
K Jack or Pinion.
L Fly-Wheel.

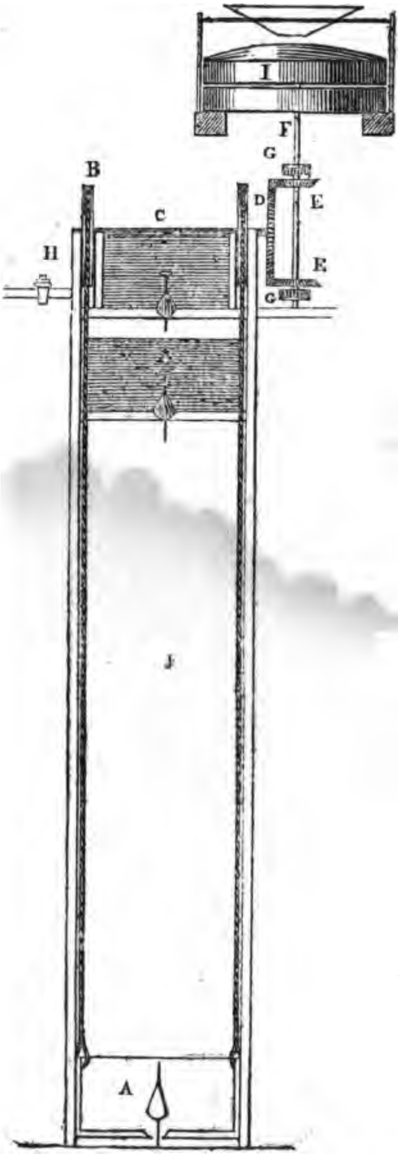
PLATE NO. II.



Explanation of Figure No. 3.—The representation given in Fig. 3. is the plan of an Engine intended particularly for great falls and for small streams of water. It is proper to remark, that the difference of expense between one for a 20 and one for a 100 feet fall, is but a trifle, merely an extension of the chains and guide rods. I should not recommend its application under falls less than 20 feet, except it were for small purposes, say 2 or 3 horses power; but it may be used to great advantage under falls from 20 to 100 feet and upwards; for instance, where there is a fall of 50 feet, a pipe of 2 1-4 inches diameter (under a 4 feet head) will discharge a quantity of water sufficient to produce a power equal to 330 pounds, moving with a velocity of 200 feet per minute; which would be nearly or quite sufficient to grind 8 bushels of corn per hour, according to the celebrated Smeaton. The first motion of this, is like the others, vibratory; which is produced by buckets suspended by chains passing over a wheel or wheels, and are filled with water, and discharged alternately as they rise and fall. These chains may be of the common kind and wind up, or gear chains to match on cogs. The motion is converted, from a vibratory, into a circular one, by a clutch, or ratchets and pinion wheels, described in this engraving, (No. 3.) I trust that in hilly and mountainous sections of the country, this form of the Engine will be much used, as great falls can be had, with little expense, and will be found of very great utility. For further particulars see specification.

3. A Bucket.
B Chain Wheel.
C Cistern.
D Bevel Gear.
E E Pinions.
F Mill Spindle.
G G Ratchet Wheels.
H Stop-cock or Gate.
I Mill Stone.
J Pit.

PLATE NO. III.



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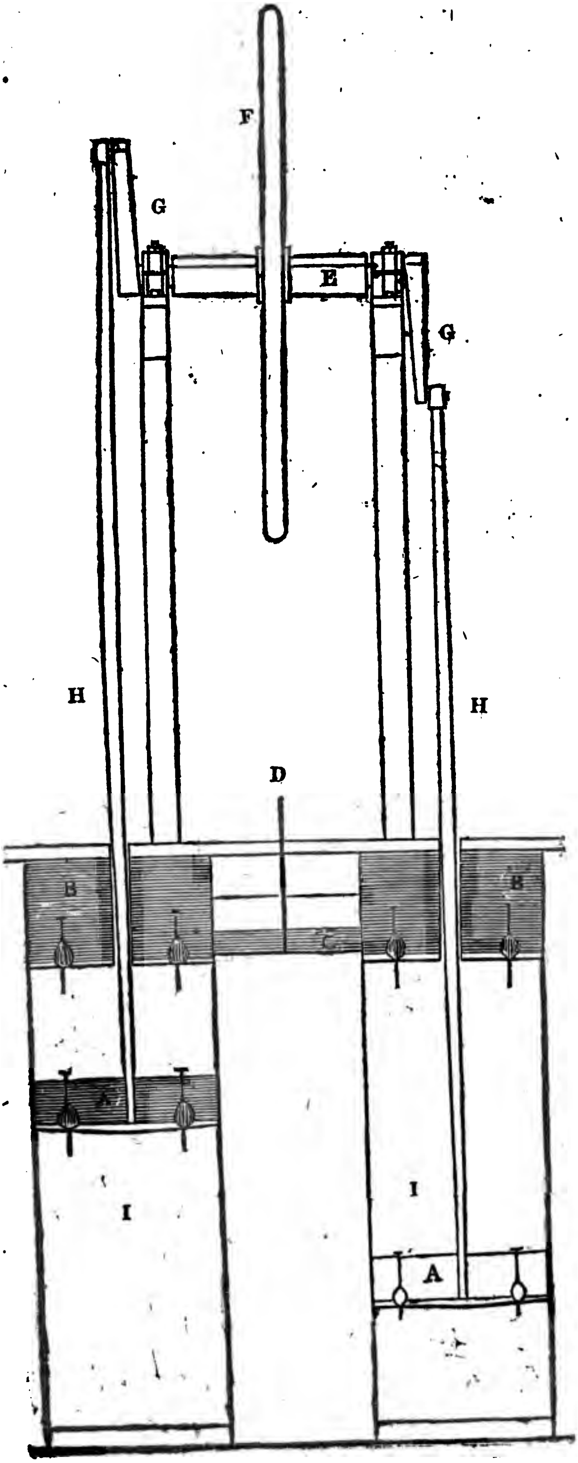
Explanation of Figure No. 4.—**Fig. No. 4** represents an engine, which from its simplicity, and cheapness of construction, will be found servicable, not only to the mechanic but also to the agriculturist. When located near a stream or fountain of water, Cider Mills, Threshing Machines, Winnowing, Washing, Churning, Woodsawing &c., may be carried on and executed with facility; and for many other agricultural purposes.

This Engine may be used for any mechanical purpose and is susceptible of all the advantages of those described in Fig. 1 & 2, by adding more sisterns and buckets; but it is principally designed for falls from 4 to 8 feet; and is calculated to be worked by a piston in a trunk or cilinder. By placing any number of these Engines in a line upon a horizontal plane, with spur gears of any given diameters upon the crank shafts (where the fly wheel is now placed) and also placing the main shaft of the mill parallel with the crank shafts, with pinions on the same to match with the spur gears, and by placing cranks in such a position that some of them will be in full power, while others are in the act of filling and discharging, it may be made a most powerful Engine.

4. A A Buckets.
B B Cistern.
C Conduit.
D Gate Rod.
E Crank Shaft.
F Fly Wheel.
G G Cranks.
H H Connecting Rods.
I I Pits.

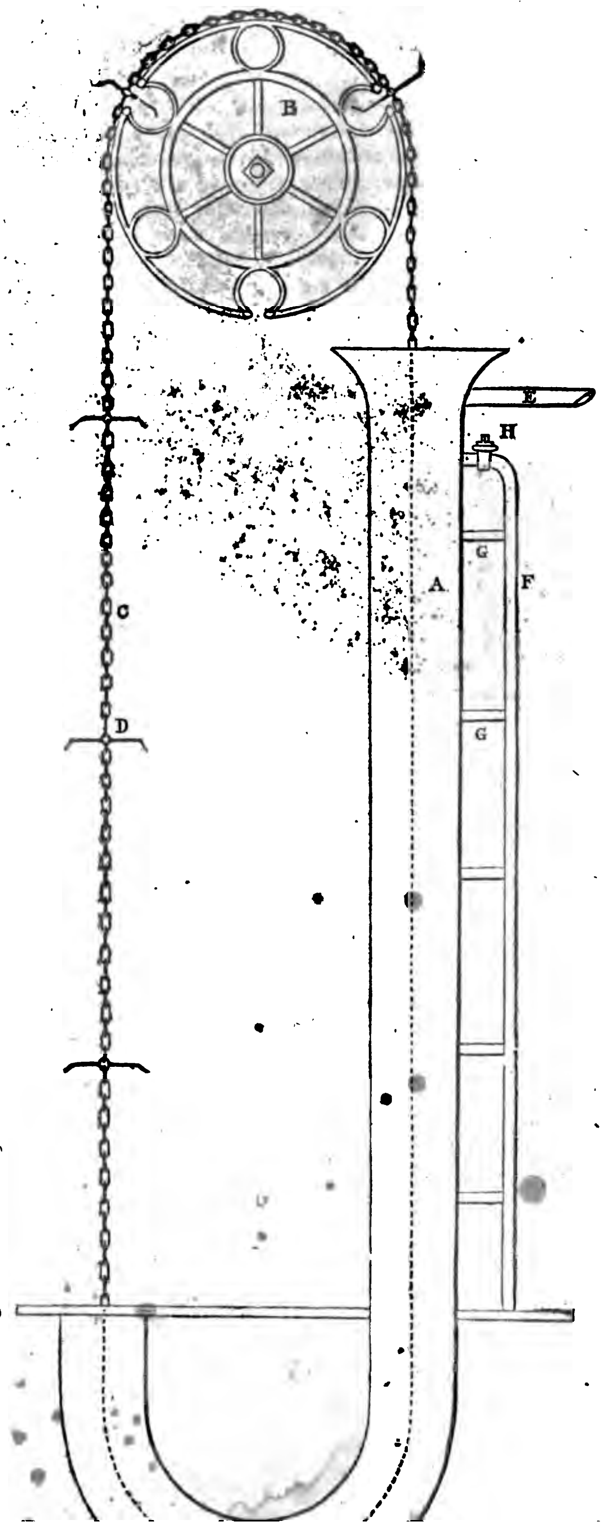
PLATE NO. IV.



Explanation of Figure No. 5.—Fig. No. 5 is a method of using water power secured to the author of this book as an improvement on the chain of buckets patented by a Mr. Cooper, in 1784. The plan however is very different from that of Mr. Cooper. The engraving will give a very good idea of the plan; A is a cylinder, or trunk, extending from the top to the bottom of the fall, with the lower end made in a circular form, to retain the water in the cylinder, or trunk, until it is balanced by the water in the raceway, and to give a circular channel for the pistons to return in—thereby dispensing with one sprocket wheel. This cylinder should be made large or small, according to the power required. I should not recommend the trunk to be made more than one foot through; but it may be made wide enough the other way to contain a quantity of water, sufficient to give any necessary power. C is an endless chain passing over the sprocket wheel B, and descends through the trunk or cylinder. D are pistons made of iron or wood, with a leather or india rubber cloth cap to prevent the water from escaping by the pistons in the cylinder. B is a sprocket wheel; any number of them may be placed on the main shaft that the length of the piston shall require. E is a spout which supplies the trunk with water; when there is a full head, the water may be let in at any point, as the pond lowers. F G G are tubes which convey the water to different parts of the cylinder, for the purpose of starting the mill which is done by turning the stop cock H.

The particular object of this method is for low heads and tide water. I think for tidewater it will supercede any wheel that has ever been used, as it is very obvious, that if the water in the pond must pass through the cylinder, so long as the water in the pond is higher than in the raceway, it must continue to give motion to the mill; and the manner the pistons rise out of the water is such that back water will not much obstruct them. This Engine is very simple, compact, and I think will be very durable. In order to ascertain the power, measure the trunk; we will suppose one to be 16 feet in length, 1 foot deep, 4 feet wide, and to contain 64 cubic feet of water, or a pressure of two tons, on the piston; this would be equal to 20 horses power, or in other words there would be 3300 pounds disposable power (the other 700 would be spent in giving a proper velocity, say 200 feet per minute) and would require a gate of about 11 inches square under a 4 feet head.

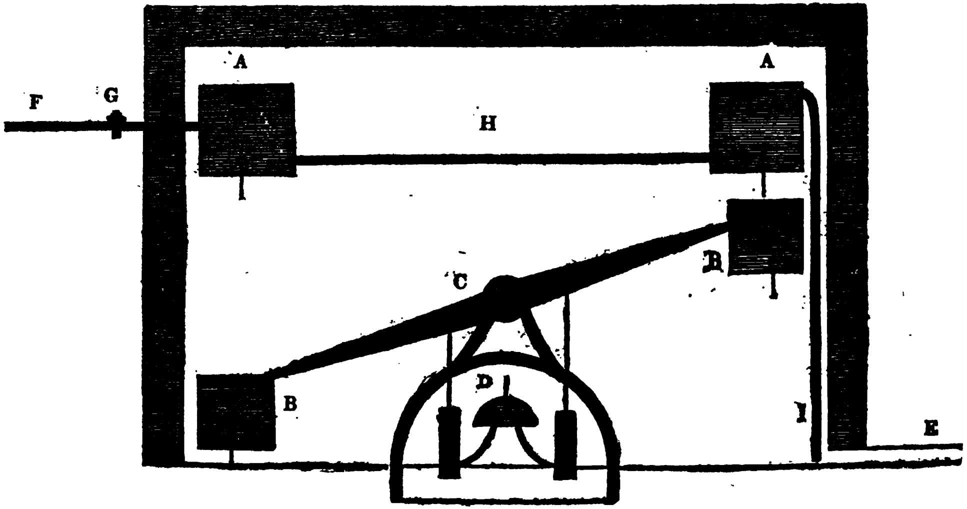
PLATE NO. V.



Explanation of Figure No. 6.—**Fig. 6 is the form** of an Engine designed particularly for raising water, which, from its simplicity of construction, and the convenience of location, which added to its probable durability, renders it a very important and valuable machine, for the purpose which it is designed. Water may be raised for kitchens, stables, yards, and gardening. Whole villages may be supplied with good spring water for cooking, or pure water for washing, which, in many places is obtained at a very great trouble and expense.

6. A A Cisterns.
B B Buckets.
C Beam.
D Force-Pump.
F Supplying Pipe.
G Stop-Cock.
H Connecting Pipe.
I Surplus Water Pipe.
E Discharging Aqueduct.

PLATE NO. VI.



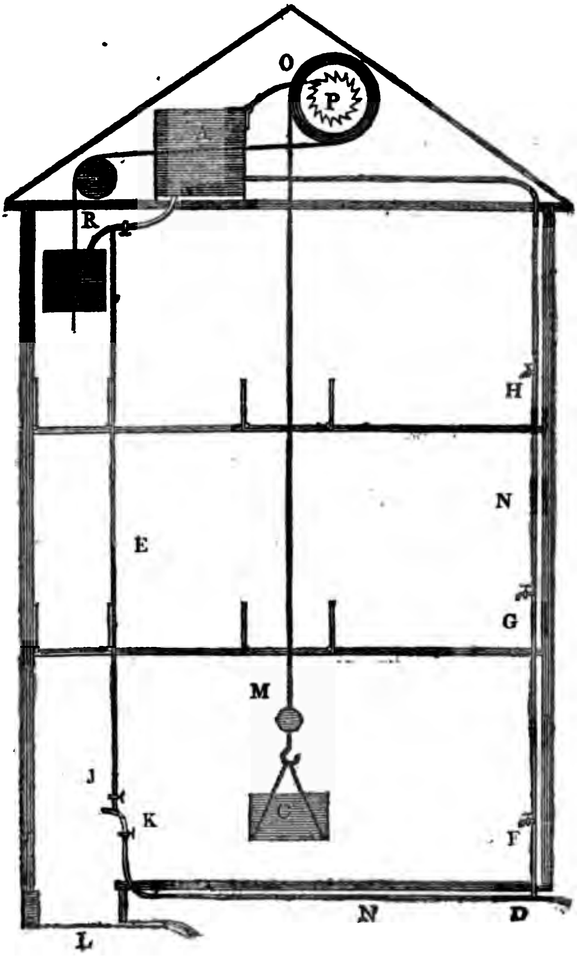
(E)

Explanation of Figure No. 7.—D is the main branch of an aqueduct, coming from a fountain. N is a pipe to carry water to the cistern, A, in the upper loft of a warehouse.—N, at the bottom, is a pipe to convey the water to the bucket at its lowest point, when goods are to be lowered down, which is done by turning the stop-cock K. B is a vessel which is filled with water from the cistern A, by turning the stop-cock I. To the bucket a rope is attached, and passing over the pulleys O O, is carried down and made fast to the bale of goods C,—which is raised by the weight of water in the bucket. When the goods are safely landed in the upper loft, the water is let off by a valve in the bottom of the bucket, and is carried out of the discharging pipe L. When it is required to lower goods from the upper loft, the bucket being at the lower point, it may be performed by turning the stop-cock K, which will fill the bucket, and when it arrives at its height, the pipe R will be immersed in water, and with the pipe E will form a cyphon, and by turning the cock J will draw the water out of the bucket. F is a stop-cock which shuts the water out of the cistern. G and H are cocks to draw water for any use required. M is a ball or weight to return the bucket, or balance it. P is a ratchet wheel on the shaft of the pulley O, in which a hand or click works, for the safety of the goods.

Perhaps it would be well to remark that when the fountain is high and powerful the cistern may be dispensed with. The machinery is simple and probably will not exceed in cost those jacks commonly in use. A boy may perform all the labor which now requires much help.

For further particulars on this subject see article 'On Raising Goods in Warehouses,' page 49.

PLATE NO. VII.



In addition to the foregoing figure and explanation I have thought proper to insert a short article on the mode of applying my engine to the purpose of raising water, by giving the size of pipes, cisterns, buckets, and a suitable place for its location, &c.—The engine should be located where a fall of 3 or 4 feet can be obtained, below the fountain or spring, which is to supply the engine;—here an excavation should be made, and stoned or planked up, leaving a cellar about seven feet in length, 2 in width, and 4 in depth,, and should be well covered over and made perfectly secure against the frost in the winter season, and also against reptiles, herbage, and mischievous boys in the summer; from the bottom of the cellar there should be a drain, or aqueduct, to carry out the water from the engine, or the surplus, after the pumps are supplied. These engines, in all their parts should be made of iron, or some permanent and durable metalic substance, and if faithfully constructed I believe they will last fifty years, with but little or no repairs; a small cylinder may be placed on the top of the beam, and parallel with it, in which a ball of any dimensions will roll back and forward, as the buckets rise and fall, the object of which is to hold the bucket up to the cistern to receive the water, so that however small the supplying stream, the buckets will fill in time,—and give motion to the pumps, or, a pendulum may be attached to the beam so as to arrest and regulate the motion. When the water is to be raised to the height of 200 feet the beam should be about 6 feet in length, and a bucket of about a 9 inch cube in the clear, attached to the end of the same; this will give a sufficient power to work the pump when filled with water, and will raise a column of water in a pipe of one inch diameter, and 200 feet in height, so as to discharge one pint at each stroke of the engine. I will here observe that the distance in a lateral direction makes no difference except friction. The resistance to the pumps is equal to a perpendicular column of water, as high as the water is to be raised. The cisterns should be as large as the buckets or larger, with a pipe inserted near the top to carry off the water when nearly full; the valves should be made in a circular form for the convenience of grinding them in emery to make them fit perfectly; or they may be leathered; their diameters should be about 3 or 4 inches. A stop-cock should be placed in the supplying pipe to regulate the water. The following table will give the size of the supplying pipe, suitable for the height to which the water is to be raised; also the quantity an engine will raise in a given time, with the size of a cistern to contain the water for a day. If this cistern be placed on an elevation above a village, it may supply many families with water,—yards &c.

Height to which the water is to be raised.	Diameter of the Discharging-pipe	Diameter of the Supplying - pipe, supposed under 1 foot head, but if under 4 feet head then half this size will be sufficient.	Quantity discharged per minute.	
200	This table is calculated for an inch, but may be used for any pipe.	1⅝ inch.	One gallon—in all cases.	2 Barrells per hour. 48 Barrells per day. 336 Barrells per week. 17472 Barrells per year.
100		1⅜		
75		1		
50		¾		
25		⅝		
12½		½		

Size of a cistern to hold 48 barrells, a cube of 6 feet 3 inches, nearly.

On Raising Goods in Warehouses.

In addition to what has been heretofore said on applying the principles of water-works discussed, in this book, to the propelling of different kinds of machinery, the power of water may be most advantageously employed by means of a bucket descending in a vertical direction, (see Fig. 7.) as an agent for raising and lowering goods in warehouses, shops, &c. especially in cities, where the inhabitants are supplied with water from a neighboring river or lake. If the city be somewhat uneven and the fountain will carry the water to the upper parts of the town, it may be several times worked over without the least detriment, and when it finally arrives at the lowest point, and being discharged into a suitable cistern it may be drawn out by suction-pumps and applied to the purposes for which it was originally intended; thus a considerable water power may be had with but little additional expense. If however the city be very level and not supplied with fresh water, as above described, then water from the river may be employed as the agent, being raised to a cistern on a tower above the principal warehouses in the city, by the ebbing and flowing of the tide, I am aware that some objection will be urged against the method last mentioned, on account of the expense of a tide mill, but believe these prejudices will be removed by a careful and candid examination of the matter. Let us just take a look at the subject, and see what might be done for the merchants in the city of Boston.

In this harbor the tide rises about 11 feet 2 inches in 24 hours, and consequently a little short of 400 tons is received and discharged on every square rod. Let us suppose 66 feet square be inclosed for a pond (over which a building may be placed, or a wharf built, so as to loose no room,) in this pond would be received 6,400 tons of water every 24 hours; which, by working it as it goes in and goes out, in an engine without waste, it would produce a power equal to 6,400 tons, descending 22 feet, which would raise half the weight, namely, 3,200 tons 44 feet; this employed for raising goods would raise the same weight the same height (that is, making no allowance for friction,) and to perform this labor by human strength according to many authors, would require about 40 men, which at $1 per day, reckoning 313 days in a year for labor, would amount to $12,520, but as I have made no allowance for friction, and as it will require some labor besides the water power, (yet two boys, one to take away the goods, let in the water &c. and the other capable of making fast the rope, and with a constitution strong enough to sing out:—*Turn the Cock, Jo; Go ahead,*—then the business might go on with facility.) We will set it at one half, say $6,260 worth of business would be performed by this simple water power. What the expense of the work would be, cannot be told exactly, but probably it would depend much on the location, which might be ascertained by finding how large a district it would require to employ such a power; however, the expense would be in proportion to the power wanted. It would appear by the above that the power here calculated would pay the interest of $521,668 50 cts. at 12 per cent.

Wind for raising water might be applied, but the power is rather uncertain.

TABLE NO. I.

[For an explanation of this table, see index.]

Square of the Gate, in Inches.

The Figure at the head of each column, designates the Size.

Head of Water above the gate.	1	2	3	4	5	6
1	208	832	1872	3328	5200	7488
2	287	1148	2583	4592	7175	10342
3	363	1452	3267	5808	8875	13068
4	416	1664	3744	6656	10300	14976
5	468	1872	4212	7484	11700	16848
6	517	2068	4653	8272	12925	18612
7	558	2232	5022	8928	13950	20088
8	575	2300	5175	9200	14375	20700
9	626	2504	5634	10116	15651	22436
10	691	2764	6219	11050	17275	24876
11	718	2872	6462	11488	17950	25848
12	728	2912	6552	11648	18200	26108
13	759	3036	6831	12144	18975	27324
14	781	3124	7029	12496	19525	28116
15	816	3264	7344	13046	20400	29376
16	832	3328	7488	13312	20800	29952
17	867	3468	7803	13872	21675	31212
18	894	3576	8046	14304	22350	32184
19	916	3664	8244	14056	22900	32976
20	938	3752	8442	15008	23450	33768
21	966	3864	8694	15456	24150	34776
22	989	3956	8901	15824	24725	35604
23	1015	4060	9135	16240	25375	36540
24	1041	4164	9369	16656	26025	37476
25	1064	4256	9576	17024	26600	38304

TABLE NO. I.—Continued.

Square of the Gate, in Inches.

The Figures at the head of each column designate the size.

Head of Water above the gate.	7	8	9	10	11	12
1	10192	13312	16828	20800	25168	29952
2	13063	18368	23247	28700	33627	41328
3	17787	23232	29403	36300	43923	52272
4	20384	26624	23696	41600	50336	59904
5	22932	29952	37908	46800	56628	67392
6	25333	33088	41877	51700	62557	74448
7	27342	35712	45196	55800	67518	80352
8	28175	36800	46575	57500	69575	82800
9	30674	40064	50706	62600	75746	90144
10	33859	42224	55971	69100	83611	99504
11	34182	45952	58158	71800	86848	103392
12	35672	46592	58968	72800	88088	104832
13	37191	48576	61479	75900	91831	109296
14	38260	49984	63261	78100	94500	112464
15	39984	52224	66096	81600	98736	117504
16	40768	53248	67392	83200	100672	119808
17	42483	55488	70227	86700	104907	124848
18	43806	57216	72414	89400	117174	128736
19	44884	58624	74196	91600	110836	131909
20	45962	60032	75978	93800	113498	135072
21	47334	61824	78246	96600	116886	139004
22	48461	63296	80109	98900	119669	142416
23	49755	64960	82215	101500	122815	146260
24	51609	66624	84321	104100	125961	149904
25	52136	68096	86184	106400	128744	153216

TABLE NO. II.

[For explanation of this table, see index.]

Size of the Gate in Inches and tenths of an Inch.

The Figure at the head of each column designates the number of horses' power.

Fall of Water, in feet.	1	2	3	4	5	6	7	8	9	10
9	22,2	44,4	62,6	88,8	111,0	133,2	155,4	177,6	199,8	222
10	20,0	40,0	60,0	80,0	100,0	120,0	140,0	160,0	180,0	200
11	18,0	36,4	54,6	72,8	91,0	109,2	127,4	145,6	163,8	182
12	16,8	33,6	50,4	64,2	84,0	100,8	117,6	134,4	151,2	168
13	15,5	31,0	46,5	62,0	77,5	93,0	108,5	124,0	139,5	155
14	14,4	28,8	43,2	57,6	72,0	86,4	100,8	115,2	129,6	144
15	13,5	27,0	40,5	54,0	67,5	81,0	194,5	108,0	121,5	135
16	12,8	25,6	38,4	51,2	64,0	76,8	89,6	102,4	115,2	128
17	11,3	22,6	33,9	45,2	56,5	67,8	79,1	90,4	101,7	113
18	11,2	22,4	33,6	44,8	56,0	67,2	78,4	89,6	100,8	112
19	10,4	20,8	31,2	41,6	52,0	62,4	72,8	83,2	93,6	104
20	10,0	20,0	30,0	40,0	50,0	60,0	70,0	80,0	90,0	100
21	9,4	18,8	28,2	37,6	47,0	56,4	65,8	75,1	84,6	94
22	9,1	18,2	27,3	36,4	45,5	54,6	63,7	72,8	81,9	91
23	8,6	17,2	25,8	34,4	40,0	51,6	60,2	68,8	77,4	86
24	8,3	16,6	24,9	33,2	41,5	49,8	58,1	66,4	74,7	83
25	8,0	16,0	24,0	32,0	40,0	48,0	56,0	64,0	72,0	80
26	7,6	15,2	22,8	30,4	38,0	45,6	53,2	60,8	68,4	76
27	7,3	14,6	21,9	29,2	36,5	43,8	51,1	58,4	65,7	73
28	7,1	14,2	21,3	28,4	35,5	42,6	49,7	56,8	63,9	71
29	6,9	13,8	20,7	27,6	34,5	41,4	48,3	55,2	62,1	69
30	6,6	13,2	19,8	26,4	33,0	39,6	46,2	52,8	59,4	66
31	6,5	13,0	19,5	26,0	32,5	39,0	45,5	52,0	58,5	65

TABLE NO. II.—Continued.

Size of the Gate in Inches.

The figures at the head of each column designate the number of horses' power.

Fall of Water in feet.	20	30	40	50	60	70	80	90	100
9	444	666	888	1110	1332	1554	1776	1998	2220
10	400	600	800	1000	1200	1400	1600	1800	2000
11	364	546	728	910	1092	1264	1456	1638	1820
12	336	504	672	840	1008	1176	1344	1512	1680
13	310	465	620	775	930	1085	1240	1495	1550
14	288	432	576	620	864	1008	1152	1296	1440
15	270	405	540	675	810	935	1080	1215	1350
16	256	384	512	640	768	896	1024	1152	1280
17	226	339	552	565	678	791	904	1017	1130
18	224	336	448	560	672	784	896	1008	1120
19	208	312	416	520	624	728	832	936	1040
20	200	300	400	500	600	700	800	900	1000
21	188	282	376	470	564	658	752	846	940
22	182	273	364	455	546	637	728	819	910
23	172	258	344	430	516	602	688	774	860
24	166	249	332	415	498	581	664	747	830
25	160	240	320	400	480	560	640	720	800
26	152	228	304	380	456	532	608	674	760
27	146	219	292	365	438	511	584	657	730
28	142	213	284	355	426	497	568	639	710
29	138	207	276	345	414	483	552	621	690
30	132	198	264	330	396	462	528	594	660
31	130	195	260	325	390	455	520	585	650

TABLE NO. II.—Continued.

Size of the Gate in Inches and tenths of an Inch.

The figure at the head of each column designates the number of horses' power.

Fall of Water in feet.	1	2	3	4	5	6	7	8	9	10
32	6,2	12,4	18,6	24,8	31,0	37,2	43,4	49,6	55,8	62
33	6,1	12,2	18,3	24,4	30,5	36,6	42,7	48,8	54,9	61
34	5,9	11,8	17,7	23,6	29,5	35,4	41,3	47,2	53,1	59
35	5,6	11,2	16,8	22,4	28,0	33,6	39,2	44,8	50,4	56
36	5,4	10,8	16,2	21,6	27,0	32,4	37,8	43,2	48,6	54
37	5,3	10,6	15,9	21,2	26,5	31,8	37,1	42,4	47,7	53
38	5.2	10,4	15,6	20,8	26,0	31,2	36,4	41,6	46,8	52
39	5,1	10,2	15,3	20,4	25,5	30,6	35,7	40.8	45,9	51
40	5,0	10,0	15,0	20,0	25,0	30,0	35,0	40,0	45,0	50
41	4,9	9,8	14,7	19,6	24,5	29,4	34,3	39,2	44,1	49
42	4,8	9,6	14,4	19,2	24,0	28,8	33,6	38,4	43,7	48
43	4,6	9,2	13,8	18,4	23,0	27,6	32,2	36,8	41,4	47
44	4,5	9,0	13,5	18,0	23,5	27,0	31,5	36,0	40,5	46
45	4,5	9,0	13,5	18,0	22,5	27,0	31,5	36,0	40,5	45
46	4,4	8,8	13,2	17,6	20,0	26,4	30,8	35,2	39,6	44
47	4,3	8,6	12,9	17,2	21,5	25,8	29,1	34,4	38,7	43
48	4,2	8,4	12,6	16,8	21,0	25,2	29,4	33,6	37,8	42
49	4,1	8,2	12,3	16,4	20,5	24,6	28,7	32,8	36,9	41
50	4,0	8,0	12,0	16,0	20,0	24,0	28,0	32,0	36,0	40
51	3,9	7,8	11,7	15,6	19,5	23,4	27,3	30,2	35,1	39
52	3,9	7,8	11,7	15,6	19,5	23,4	27,3	31,2	35,1	39
53	3,8	7,6	11,4	15,2	19,0	22,8	26,6	30,4	34,2	38
54	3,8	7,6	11,4	15,2	19,0	22,8	26,6	30,4	34,2	38

TABLE NO. II.—Continued.

Size of the Gate in Inches.

The figures at the head of each column designate the number of horses' power.

Fall of Water in feet.	20	30	40	50	60	70	80	90	100
32	124	186	248	310	372	434	496	558	620
33	122	183	244	305	366	427	488	549	
34	118	177	236	295	354	413	472	531	590
35	112	168	224	280	336	492	448	504	560
36	108	162	216	270	324	378	432	486	540
37	106	159	212	265	318	371	424	477	530
38	104	156	208	260	312	364	416	468	520
39	102	153	204	255	306	357	408	459	510
40	100	150	200	250	300	350	400	450	500
41	98	147	196	245	294	343	392	441	490
42	96	144	192	240	288	336	384	432	480
43	94	141	188	235	282	329	376	423	470
44	92	138	184	230	276	322	368	414	460
45	90	135	180	225	270	315	360	405	450
46	88	132	176	220	264	308	352	396	440
47	86	129	172	215	258	301	344	387	430
48	84	126	168	210	252	294	336	378	420
49	82	123	164	215	246	287	328	369	410
50	80	120	160	300	240	280	320	360	400
51	78	117	156	195	234	273	312	351	390
52	78	117	156	195	234	273	312	351	390
53	76	114	152	190	228	266	304	342	380
54	76	114	152	190	228	266	304	342	380

TABLE NO. II.—Continued.

Size of the Gate in Inches and tenths of an Inch.

The Figure at the head of each column designates the number of horses' power.

Fall of Water, in feet.	1	2	3	4	5	6	7	8	9	10
55	3,7	7,4	11,1	14,8	18,5	22,2	25,9	29,6	33,3	37
56	3,7	7,4	11,1	14,8	18,5	22,2	25,9	29,6	33,3	37
57	3,6	7,2	10,8	14,4	18,0	21,6	25,2	28,8	32,4	36
58	3,6	7,2	10,8	14,4	18,0	21,6	25,2	28,8	32,4	36
59	3,5	7,0	10,5	14,0	17,5	21,0	24,5	28,0	31,5	35
60	3,5	7,0	10,5	14,0	17,5	21,0	24,5	28,0	31,5	35
61	3,4	6,8	10,2	13,6	17,0	20,4	23,8	27,2	30,6	34
62	3,4	6,8	10,2	13,6	17,0	20,4	23,8	27,2	30,6	34
63	3,3	6,6	9,9	13,2	16,5	19,8	23,1	26,4	29,7	33
64	3,3	6,6	9,9	13,2	16,5	19,8	23,1	26,4	29,7	33
65	3,2	6,4	9,6	12,8	16,0	19,2	22,4	25,6	28,8	32
66	3,2	6,4	9,6	12,8	16 0	19,2	22,4	25,6	28,8	32
67	3,1	6,2	9,3	12,4	15,5	18,6	21,7	24,8	27,9	31
68	3,1	6,2	9,3	12,4	15,5	18,6	21,7	24,8	27,9	31
69	3,0	6,0	9,0	12,0	15,0	18,0	21,0	24,0	27,0	30
70	3,0	6,0	9,0	12,0	15,0	18,0	21,0	24,0	27,0	30
71	2,9	5,8	8,7	11,6	14,5	17,4	20,3	23,2	26,1	29
72	2,9	5,8	8,7	11,6	14,5	17,4	20,3	23,2	26,1	29
73	2,9	5,8	8,7	11,6	14,5	16,8	20,3	23,2	26,1	29
74	2,8	5,6	8,4	11,2	14,0	16,8	19,6	22,4	25,2	28
75	2,8	5,6	8,4	11,2	14,0	16,8	19,6	22,4	25,2	28
76	2,8	5,6	8,4	11,2	14,0	16,8	19,6	22,4	25,2	28
77	2,7	5,4	8,1	10,8	13,5	16,2	18,9	21,6	24,3	27

TABLE NO. II.—Continued.

Size of the Gate in Inches.

The figures at the head of each column designate the number of horses' power.

Fall of Water in feet.	20	30	40	50	60	70	80	90	100
55	74	111	148	185	222	259	296	333	370
56	74	111	148	185	222	259	296	333	370
57	72	108	144	180	216	252	288	324	360
58	72	108	144	180	216	252	288	324	360
59	70	105	140	175	210	245	280	315	350
60	70	105	140	175	210	245	280	315	350
61	68	102	136	170	204	238	272	306	340
62	68	102	136	170	204	238	272	306	340
63	66	99	132	165	198	231	264	297	330
64	66	99	132	165	198	231	264	297	330
65	64	96	128	160	192	224	256	288	320
66	64	96	128	160	192	224	256	288	320
67	62	93	124	155	186	217	248	279	310
68	62	93	124	155	186	217	248	279	310
69	60	90	120	150	180	210	240	270	300
70	60	90	120	150	180	210	240	270	300
71	58	87	116	145	174	203	232	261	290
72	58	87	116	145	174	203	232	261	290
73	68	87	116	145	174	203	232	261	290
74	56	84	112	140	168	196	224	252	280
75	56	84	112	140	168	196	224	252	280
76	56	84	112	140	168	196	224	252	280
77	54	81	108	135	162	189	216	243	270

TABLE NO. II.—Continued.

Size of the Gate in Inches and tenths of an Inch.

The figure at the head of each column designates the number of horses' power.

Fall of Water in feet.	1	2	3	4	5	6	7	8	9	10
78	2,7	5,4	8,1	10,8	13,5	16,2	18,9	21,6	24,3	27
79	2,7	5,4	8,1	10,8	13,5	16,2	18,9	21,6	24,3	27
80	2,6	5,2	7,8	10,4	13,0	15,6	18,2	20,8	23,4	26
81	2,6	5,2	7,8	10,4	13,0	15,6	18,2	20,8	23,4	26
82	2,6	5,2	7,8	10,4	13,0	15,6	18,2	20,8	23,4	26
83	2,5	5,0	7,5	10,0	12,5	15,0	17,5	20,0	22,5	25
84	2,5	5,0	7,5	10,0	12,5	15,0	17,5	20,0	22,5	25
85	2,5	5,0	7,5	10,0	12,5	15,0	17,5	20,0	22,5	25
86	2,4	4,8	7,2	9,6	12,0	14,4	16,8	19,2	21,6	24
87	2,4	4,8	7,2	9,6	12,0	14,4	16,8	19,2	21,6	24
88	2,4	4,8	7,2	9,6	12,0	14,4	16,8	19,2	21,6	24
89	2,3	4,6	6,9	9,2	11,5	13,8	16,2	18,4	20,7	23
90	2,3	4,6	6,9	9,2	11,5	13,8	16,2	18,4	20,7	23
91	2,3	4,6	6,9	9,2	11,5	13,8	16,2	18,4	20,7	23
92	2,2	4,4	6,6	8,8	11,0	13,2	15,4	17,6	19,8	22
93	2,2	4,4	6,6	8,8	11,0	13,2	15,4	17,6	19,8	22
94	2,2	4,4	6,6	8,8	11,0	13,2	15,4	17,6	19,8	22
95	2,1	4,2	6,3	8,4	10,5	12,6	14,7	16,8	18,9	21
96	2,1	4,2	6,3	8,4	10,5	12,6	14,7	16,8	18,9	21
97	2,1	4,2	6,3	8,4	10,5	12,6	14,7	16,8	18,9	21
98	2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20
99	2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20
100	2,0	4,0	6,0	8,0	10,0	12,0	14,0	16,0	18,0	20

TABLE NO. II.—Continued.

Size of the Gate in Inches.

The figures at the head of each column designate the number of horses' power.

Fall of Water in feet.	20	30	40	50	60	70	80	90	100
78	54	81	108	135	162	189	216	243	270
79	54	81	108	135	162	189	216	243	270
80	52	78	104	130	156	182	208	174	260
81	52	78	104	130	156	182	208	174	260
82	52	78	104	130	156	182	208	174	260
83	50	75	100	125	150	175	200	225	250
84	50	75	100	125	150	175	200	225	250
85	50	75	100	125	150	175	200	225	250
86	48	72	96	120	144	168	192	216	240
87	48	72	96	120	144	168	192	216	240
88	48	72	96	120	144	168	192	216	240
89	46	69	92	115	138	161	184	207	230
90	46	69	92	115	138	161	184	207	230
91	46	69	92	115	138	161	184	207	230
92	44	66	88	110	132	154	176	198	220
93	44	66	88	110	132	154	176	198	220
94	44	66	88	110	132	154	176	198	220
95	42	63	84	105	126	147	168	189	210
96	42	63	84	105	126	147	168	189	210
97	42	63	84	105	126	147	168	189	210
98	40	60	80	100	120	140	160	180	200
99	40	60	80	100	120	140	160	180	200
100	40	60	80	100	120	140	160	160	200

STRENGTH AND PROPORTION OF BEAMS.

The best proportion that can be given to a beam, for one of my hydraulic engines is to give 1¼ inch in depth at the fulcrum, to every foot in length of the beam, and allow ⅙ of the depth for the breadth; the beam should be so diminished from the centre as to be but ⅓ as deep at the ends as at the fulcrum. And it is believed that a beam made of two bars of square iron or wood, of a size equal to the breadth of a solid beam, herein laid down, with the ends made solid, or equally permanent, and spread at the fulcrum, so as to give a depth as required in the rule, would be as strong or stronger than the solid beam, as the strain would come more on the cohesive or lengthwise strain than it would upon the cross or transverse strain.

Length of the beam.	Area of a cross section of the beam at the fulcrum.	Strength of a White-Oak Beam.	Strength of a Cast-Iron Beam.	Strength of a Wrought Iron Beam.
10	25	2500	12500	37500
11	32⅔	3108	16330	48990
12	37½	3375	17750	53250
13	42⅔	3626	21330	63990
14	52½	4200	26250	78750
15	60	4500	30000	90000
16	66⅔	4666	33330	99990
17	73½	4777	36550	109650
18	81	4860	40500	120500
19	96	5280	48000	144000
20	104	5200	52000	156000

LEAD PIPES.

The following is a list of the average weight and cost of Lead Pipes, per rod, of different diameters, in the clear, with a thickness sufficient to bear a pressure of 300 feet head of water.

Size of the Bore.	Weight.	Cost per rod.
One fourth,	8	64
One half,	12	96
Three fourths,	20	1,60
One inch,	33	2,64
One and one fourth,	45	3,60
One and a half,	60	4,80
One and three fourths,	70	5,60
Two inches,	84	6,72
Three do.	100	8,00
Four do.	172	13,76
Six do.	300	24,00
Eight do.	349	37,92
Ten do.	608	48,64
Twelve do.	674	53,92
Sixteen do.	956	76,48
Twenty do.	1500	120,00
Twenty-four do.	2050	164,00

COPPER PIPES.

A table of the weight and cost of Copper Pipes, one sixteenth of an inch thick,—of different diameters.

Diameter.	Weight.	Cost per foot
Two inches.	1,8	67
Three do.	2,4	1,00
Four do.	3,0	1,35
Five do.	3,12	3,68
Six do.	4,8	2,00

CAST IRON PIPES.

A table of the diameters, weight, and cost of Cast Iron Pipes.

Diameters.	Pounds.	Cost per foot.	Cost 1-2 mile.	Cost per mile.
Five inches,	25,90	1,30	3,432,00	6,864,00
Six do.	30,60	1,53	4,039,00	8,078,00
Seven do.	35,34	1,77	4,673,00	9,346,00
Eight do.	40,05	2,00	5,280,00	10,560,00
Nine do.	44,76	2,24	5,913,50	11,827,00
Ten do.	49,47	2,47	6,520,50	13,041,00
Eleven do.	54,18	2,70	7,128,00	14,256,00
Twelve do.	58,89	2,94	7,761,50	15,523,00
Thirteen do.	63,60	3,18	8,395,00	16,790,00
Fourteen do.	68,31	3,42	9,028,50	18,657,00
Fifteen do.	73,02	3,66	9,662,05	19,324,00

SHEET IRON PIPES.

A table of the weight and cost of Sheet Iron Pipes of different diameters, per rod, with the present prices.

Diameters.		Weight.	Cost per foot.	Cost per rod.
Three inches,	at 12½ cts.	2 lbs.	24	3,96
Four do.	do.	2¾	33	5,44
Five do.	do.	3½	42	6,93
Six do.	do.	4	48	7,92
Seven do.	do.	4¾	57	9,30
Eight do.	do.	5½	66	10,89
Nine do.	do.	6¼	75	12,32
Ten do.	do.	7	84	13,86
Eleven do.	do.	7½	90	14,85
Twelve do.	do.	8	96	15,79

For further information respecting Sheet Iron Pipes, see Sir H. Davy's Discovery, resulting from his Electro-Chemical Theory,—in the last part of this work.

WOODEN PIPES.

A table of the diameters and cost of boring Wooden Pipes, according to the prices, in the city of Boston, to which may be added the cost of them in whatever section of the country they are to be used.—I would here observe that the best method of connecting wooden pipes, is by inserting iron tubes at the joints.

Diameters.	Cost per foot.	Cost per rod.
Two inches, -	4	66
Three do. -	7	1,15
Four do. -	10	1,65
Five do. -	13	2,14
Six do. -	16	2,64
Seven do. -	19	3,13
Eight do. -	22	3,63

CUBES OF WATER.

A table showing the weight and cubic feet in different cubes of water, from one to thirteen feet.

Cubes of Water.	Cubic feet in a cube.	Weight in pounds.
One foot, -	1	62½
Two do. -	8	500
Three do. -	27	1,687½
Four do. -	64	4,000
Five do. -	125	7,812½
Six do. -	216	13,500
Seven do. -	343	21,437½
Eight do. -	512	32,000
Nine do. -	729	45,562½
Ten do. -	1000	62,500
Eleven do. -	1331	82,187½
Twelve do. -	1728	108,000
Thirteen do. -	2197	137,312½

WEIGHT OF TIMBER, &c.

A table showing the weight of one cubic foot of several kinds of Timber and other materials.

Ash,	$47\frac{5}{10}$	Granite,	164
Beach,	$43\frac{3}{10}$	Gravel,	120
Brass,	523	Iron, malleable,	475
Brick,	115	Lead,	709
Brick-work,	117	Mahogany,	35
Cast Iron,	450	Marble,	169
Clay,	125	Oak,	52
Coal, Newcastle,	$79\frac{30}{100}$	Pine, yellow,	$26\frac{3}{4}$
Earth,	95 to 125	Water,	$62\frac{1}{2}$
Elm,	34	Zinc,	$439\frac{1}{4}$

COHESIVE STRENGTH OF TIMBER, &c.

A table giving the cohesive strength of several Beams and Bars, one inch square. The amount placed opposite each kind, shows its cohesive strength or the weight required to break it, when drawn in the direction of its length.

A bar of malleable iron, 1 inch square will bear	76,400
Cast iron,	18,656
Brass,	35,600
Hemp Rope	19,600
Ivory,	15,700
Lead,	430
Oak,	7,850
Box, and Plumb Tree,	7,850
Elm, Ash and Birch,	6,070
Walnut and Plumb,	5,360
Red Fur, Holly and Crab,	5,000
Cherry and Hazle,	4,760
Alder, Asp, Willow and Birch,	4,290

WEIGHT OF SHEET IRON, COPPER AND LEAD.

A table showing the weight and cost of one foot square of Cast and Malleable Iron, Copper, and Lead, from one sixteenth to one inch thick.

CAST IRON.	Weight.	Cost.
One sixteenth,	2,06$\frac{6}{10}$	,12
One eighth,	4,13$\frac{3}{10}$	,24
Three sixteenths,	7,04$\frac{3}{10}$	,36
One fourth,	9,10$\frac{6}{10}$	,48
One Half,	19,05$\frac{2}{10}$	,97
Three fourths,	28,15$\frac{8}{10}$	1,45
One inch,	38,10$\frac{4}{10}$	1,93
MALLEABLE IRON.		
One sixteenth,	2,07$\frac{8}{10}$	,16
One eighth,	4,15$\frac{6}{10}$	,32
Three sixteenths,	7,07$\frac{4}{10}$	,49
One fourth,	9,15$\frac{2}{10}$	,65
One half,	19,14$\frac{4}{10}$	1,30
Three fourths,	29,13$\frac{6}{10}$	1,95
One inch,	39,12$\frac{8}{10}$	2,60
COPPER.		
One sixteenth,	2,15	,74
One eighth,	5,14	1,49
Three sixteenths,	8,13	2,21
One fourth,	11,12	2,93
One half,	23,08	5,87
Three fourths,	35,04	8,81
One inch,	47,00	11,75
LEAD.		
One sixteenth,	3,11	,26
One eighth,	7,06	,52
Three sixteenths,	11,01	,77
One fourth,	14,12	1,04
One half,	29,08	2,07
Three fourths,	44,04	3,10
One inch,	59,00	4,13

WEIGHT OF BAR IRON.

A table showing the weight and cost of ten feet in length, Round Iron of different sizes, also Cast and Malleable Iron, ten feet in length and from one half to three inches square.

ROUND MALLEABLE.

		Weight.	Cost.
Three eighths,	4¾ cts. per lb.	4,07	,29
One half	-	8,02	,49
Five eighths,	-	10,09	,53
Three fourths,	-	14,13	,63
Seven eighths,	-	20,07	,97
One inch,	-	26,07	1,25
One and one eihgth,		29,01	1,36
One and one fourth,		32,12	1,48
One and one half,	-	56,00	2,66

SQUARE MALLEABLE.

One half inch,	4¾ cts. per lb.	8,03	,39
Five eighths,	-	12,12	,60
Three fourths,	-	18,07	,88
Seven eighths,	-	24,09	1,16
One inch,	-	32,12	1,55
One and one half inch,		73,11	3,49
Two inches,	-	131,00	6,20
Three inches,	-	204,11	13,92

SQUARE CAST.

One half inch,	5 cts. per lb.	,08	,40
Five eighths,	-	,12½	,62
Three fourths,	-	,18	,90
Seven eighths,	-	,24½	1,22
One inch,	-	,32	1,60
One and one half,	-	,72	3,50
Two inches,	-	1,28	6,40
Three inches,	-	2,88	14,40

CHAINS.

A table showing the size, weight, price per pound, cost per fathom, and strength of chains, of different sizes.

Size.	Weight.	Price per lb.	Per fathom.	Strength to raise.
5-16ths,	6	15 cts.	90 cts.	Tons. 1
3-8ths,	9	14	1,26	2
7-16ths,	11	13	1,43	3
½	14	12	1,68	4
9-16ths,	18	11	1,98	5
5-8ths,	22	10½	2,31	7
11-16ths,	27	10	2,70	8
¾	32	9½	3,04	10
13-16ths,	38	9	3,52	12
⅞	44	8½	3,74	14
15-16ths,	50	8½	4,25	16
1	56	8	4,48	19
1 1/16	63	7½	4,72	22
1⅛	70	7½	5,25	27
1 3/16	78	7½	5,85	32
1¼	86	7½	6,45	37
1 5/16	95	7½	7,12	40
1⅜	104	7½	7,80	44

ROPES.

A table of the size, weight, and cost per fathom, of Bolt Rope, and the weight, ropes of the different sizes will bear.

Circumferences.	Weight.	Cost.	Strength.
One and an half inch, 12 cts. lb.	1,00 oz.	,12	3150
Two and an half,	,14	,10½	8100
Three inches,	,12	,09	9900
Three and one fourth,	,09	,06¼	13500
Three and on half,	,03	,02½	15000

The method of obtaining the size of a rope is to measure the circumference.

STRENGTH OF WOOD.

A table of the cross or transverse strain of different kinds of Wood, each piece being one foot long and one inch broad and deep.

Oak, - - - - - -	660
Ash, - - - - -	635
Beach, - - - -	677
Elm, - - - - -	540
Walnut, green, - - - -	487
Spruce, American, - - -	570
Hard Pine, do. - - -	658
Birch, - - - - -	517
Poplar, Lombard, - - -	327
Chestnut, - - - - -	250

OF WEIGHTS.

A table of Weights, equal to Horses' power,—in table No. 2.

Number of horses' power.	Disposable power, or constant pressure, when moving with a velocity of 200 feet per minute.	Force or pressure when held in an equilibrium.	Number of horses' power.	Disposable power or constant pressure,—when moving with a velocity of 200 feet per minute.	Force of pressure, when held in an equilibrium.
1	165	200	20	3300	4000
2	330	400	30	4950	6000
3	495	600	40	6600	8000
4	660	800	50	8250	10000
5	825	1000	60	9900	12000
6	990	1200	70	11550	14000
7	1155	1400	80	13200	16000
8	1320	1600	90	14850	18000
9	1485	1800	100	16500	20000
10	1650	2000			

A Table of the CONTENTS OF A PIPE one inch in diameter, for any required height, from one to two hundred feet.

Feet in height.	Cubic inches.	Avoir. oz.	Wine gallons.
1	9,42	5,46	,0407
2	18,85	10,92	,0816
3	28,27	16,38	,1224
4	37,70	21,85	,1632
5	47,12	27,31	,2040
6	56,55	32,77	,2423
7	65,97	38,23	,2848
8	75,40	43,69	,3264
9	84,82	49,16	,3671
10	94,25	54,62	,4080
20	188,49	109,24	,8160
30	282,74	163,86	1,2240
40	376,99	218,47	1,6300
50	471,24	273,09	2,0400
60	565,49	327,71	2,4480
70	659,73	382,33	2,8560
80	753,98	436,95	3,2640
90	848,23	491,57	3,6700
100	942,48	546,19	4,0800
125	1177,50	682,50	5,0875
150	1413,47	819,28	6,1200
175	1648,50	955,50	7,1275
200	1884,96	1092,38	8,1600

Although the foregoing table gives only the contents of a pipe one inch in diameter it will serve as a standard for pipes of any other size by observing the following

RULE :—Multiply the numbers found in the table against the height, by the square of the diameter of the pipe, and the product will be the number of cubic inches, avoirdupois ounces, and wine gallons of water, that the given pipe will contain.

Example,—How many wine gallons of water are contained in a pipe six inches diameter, and sixty feet long ?

24480×36=88,1280 wine gallons.

How many cubic inches of water are contained in a pipe five inches diameter and forty feet long ?

376,99×5×5=9424,75 cubic inches.

How many avoirdupois ounces of water are contained in a pipe four inches diameter and twenty feet long ?

Against 20 I find 109,24 and
Against 5 I find 27,31

Avoirdupois oz. 136,55×4×4=2184,50.

The wine gallon contains 231 cubic inches and the new imperial gallon 277,274 cubic inches, therefore to reduce the wine to the imperial gallon, divide by 1,20032. This number is obtained by dividing the cubic inches in the imperial gallon by the cubic inches in the wine gallon. A.

OF FALLING BODIES.

A table of the motion of Falling Bodies, supposed in vacuo.

Distance passed thro' —in feet.	The velocity acquired by the fall, in feet and parts—counted per second.	Seconds of time that a body is supposed to be falling.	Distance passed thro' in said time, in feet and parts.	Velocity per second acquired at the end of every second, in feet and parts.
1	8,1	,125	,25	4,
2	11,4	,25	1,01	8,1
3	14,	,5	4,05	16,2
4	16,2	,75	9,11	24,3
5	18,	1,	16,2	32,4
6	19,84	2,	64,8	64,8
7	21,43	3,	145,8	97,2
8	22,8	4,	259,2	129,6
9	24,3	5,	305,	162,
10	25,54	6,	583,2	194,4
11	26,73	7,	793,8	226,8
12	28,	8,	1036,8	259,2
13	29,16	9,	1312,2	291,6
14	30,2	10,	1620,	324,
15	31,34	30,	14580,	972,
16	32,4	60,	58320,	1944,
17	33,32			
18	34,34			
19	35,18			
20	36,2			
21	37,11			
36	48,6			
49	56,7			
64	64,8			
100	81,			
144	97,2			

A TABLE FOR PUMP-MAKERS.

Height of the Pump, in feet, above the surface of the well.	Diameter of the bore.		Water discharged per minute,——in wine measure.	
	Inches.	100th parts of an Inch.	Gallons.	Pints.
10	6	93	81	6
15	5	66	54	4
20	4	90	40	7
25	4	38	32	6
30	4	00	27	2
35	3	70	23	3
40	3	46	20	3
45	3	27	18	1
50	3	10	16	3
55	2	95	14	7
60	2	84	13	5
65	2	72	12	4
70	2	62	11	5
75	2	53	10	7
80	2	45	10	2
85	2	38	9	5
90	2	31	9	1
95	2	25	8	5
100	2	19	8	1

"All pumps should be so constructed as to work with equal ease, in raising the water to any given height above the surface of the well; and this may be done by observing a due proportion between the diameter of that part of the pump bore in which the piston or bucket works, and the height to which the water must be raised.

"For this purpose, I have calculated the foregoing table; in which the handle of the pump is supposed to be a lever, increasing the power five times,—that is, the distance or length of that part of the handle that lies between the fulcrum on which it moves, and the top of the pump-rod to which it is attached, to be only one fifth part of the length of the handle, from the said fulcrum to the part where the man (who works the pump) applies his force or power.

"In the first column of the table, find the height at which the pump must discharge the water above the surface of the well, then in the second column you have the diameter of that part of the bore in which the piston or bucket works, in inches and hundreth parts of an inch; in the third column is the quantity of water (in wine measure) that a man of common strength can raise in a minute, and by constructing according to this method, pumps of all heights may be wrought by a man of ordinary strength, so as to be able to hold out for an hour."

JAMES FERGUSON.

ON FALLING BODIES,—*Supposed in vacuo.*

Although I have introduced a table on falling bodies, (see page 70,) I have thought it might sometimes be necessary to descant more minutely into fractions, and not only give the velocity through a certain distance, but also the distance required for a given velocity.

1st. The perpendicular height of the fall of water being given in feet and decimals of feet, the velocity that the water will acquire per second, expressed in feet and decimals, may be found by the following rule:

Multiply the constant number, 64,2882 by the given height, and the square root of the product is the velocity required.

Note.—The velocities thus obtained will be only theoretical;—that is, the velocity any body would acquire by falling through such height, *in vacuo*; the velocity in reality will generally be three or four tenths less.

2d. The uniform velocity of a fluid being given, expressed in feet and decimals of feet per second, the height of the column or fall, to produce such velocity may be found by the following rule:

Multiply the given velocity into itself, and divide the product by 64,2882.—the quotient will be the height required, expressed in feet and decimals.

Aricle 1.

OF THE FIRST PRINCIPLES OF MECHANICS.

MOTION may be said to be the beginning or foundation of all mechanics; because no mechanical operation can be performed without motion.

AXIOMS OF MOTION AND REST.

1. A body at rest will continue so forever, unless it is put in motion by some force impressed.

2. A body in motion will continue so forever, with the same velocity in the same direction, unless resisted by some force.

3. The impulse that gives motion, and the resistance that destroys it, are equal.

4. Causes and effects are equal, or directly proportional.

POSTULATUMS;—or, POSITIONS readily admitted.

A quadruple impulse, or moving power, is requisite to communicate double velocity to a body;—therefore a quadruple resistance is requisite to destroy double velocity in a body, by axiom 3d.

The impulse we may call power, and the resistance that it overcomes, the effect produced by that power.

COROLLARY.

Consequently, the powers of bodies in motion to produce effects, are as the squares of their velocity; that is, a double velocity, in a moving body, produces four times the effect.

Art. 2.

OF THE PRINCIPLES OF MECHANICS.

There are two principles which are the foundation of all mechanical motion and mechanical powers, viz.—Gravity and Elasticity;——or, Weight and Spring.

By one or the other of these principles or powers, every mechanical operation is performed.

Gravity, in the extent of the word, means every species of attraction, but more especially to, and mutually between, all bodies; and is evident between the sun and its planetary attendants, as also between the earth and the moon. But we will only consider it, as it relates to that tendency which all bodies on the earth have, to fall towards its centre; thus far it concerns the mechanical arts, and its laws are as follows, viz.—

LAWS OF GRAVITY.

1. Gravity is common to all bodies, and mutual between them.

2. It is in proportion to the quantity of matter in bodies.

3. It is exerted every way from the centre of gravity in attracting bodies, in right-lined directions;—therefore all bodies on the earth tend to the centre of gravity of the earth.

4. It decreases as the square of the distances increase; that is, if a body on the earth, was to be removed to double the distance from the centre of gravity of the earth, about 4000 miles high, it would there have but one fourth of the gravity or weight it had when on the ground: but a small height from the surface of the earth, (50 or 100 feet) makes no sensible difference in gravity.

By the 3d law, it follows, that all bodies descending freely by their gravity, tend towards the earth in right lines, perpendicular to its surface, and with equal velocities (abating for the resistance of the air,) as is evident by the 2d law.

Art. 3.

ELASTICITY.

Elasticity is that power or property, by which a body recovers its figure, or dimensions, after it has been changed by any external action; such as a spring that is bent or wound up, heated air or steam confined in a vessel, &c. By this power many mechanical operations are performed.

The limits of the prodigious power of repulsion—which takes place between the particles of heated air and of steam, are not yet known. Their effects are seen in the explosion of gun-powder, the bursting and cracking of wood in the fire, &c. In short, in every instance where steam could not find room to expand itself, it has burst the vessel that contained it, endangering the lives of those who were near it.

Having premised what was necessary to the right understanding of mechanics, which mostly depends upon the principles of gravitation, we come in the next place to consider the objects thereof, viz. the nature, kinds, and various effects of motion, and moving bodies, and the structure and mechanism of all kinds of machinery called mechanical power, whether simple or compound.

Art. 4.

OF MOTION AND ITS GENERAL LAWS.

Motion is the continual and successive change of space or place, and is either absolute or relative.

Absolute motion is the removal of a body from one part of space to another, as the motion of the earth in its orbit.

Relative motion is the motion one body has with respect to another, such as the difference of motion of the flight of two birds, or of two ships sailing.

Art. 5.

Motion is either equable, accelerated, or retarded.

Equable motion is when a body passes on equal distances in equal times.

Accelerated motion is that which is continually increased; such is the motion of falling bodies.

Retarded motion is that which continually decreases; such is the motion of a cannon ball, thrown perpendicularly upwards.

Art. 6.

The momentum or quantity of motion, is all the power or force which a moving body has to strike an obstacle, to produce effects, and is equal to that impressed force by which a body is compelled to change its place, by Axiom 3d, Art. 1; which ought to be distinguished by two names, viz. instant and effective momentums.

1. The instant momentum or force of moving bodies, is in the compound ratio of their quantities of matter, and simple velocities conjoined; that is, as the weight of one body, multiplied into its velocity, is to the weight of another body, multiplied into its velocity, so is the instant force of one to the instant force of the other. If one body has 4 lbs. of matter and one degree of velocity, and another has 2 lbs. of matter and 4 degrees of velocity, then the momentum of their strokes will be as 4 is to 8; that is, supposing them to be instantaneously stopped by an obstacle.

2. The effective momentum, or force of moving bodies, is all the effect they will produce by impinging on any yielding obstacle; and is in the compound duplicate ratio of their quantities (or weight) multiplied into the squares of their velocities; that is, as the weight of a body, multiplied into the square of its velocity, is to the weight of another body, multiplied into the square of its velocity, so is the effective momentum of the one to that of the other. If one body has 2 lbs. of matter and 2 degrees of velocity, and another body has 2 lbs. of matter and 4 degrees of velocity, then their effective momentums are as 8 to 32; that is, a double velocity produces a quadruple effect.

Art. 7.

The general laws of motion are the three following, viz.

Law 1. Every body will continue in its present state, whether it be at rest or moving uniformly in a right line, except it be compelled to change that state by some force impressed.

Law 2. The change of motion or velocity is always proportional to the square root of the moving force impressed, and in a right line with that force, and not as the force directly.

Law 3. Action and reaction are always equal—and in contrary directions to each other.

Art. 8.

OF THE MOMENTUM OR FORCE OF BODIES IN MOTION.

1. If two non-elastic bodies, each having the same quantity of matter, move with equal velocities against each other, they will destroy each other's motion—and remain at rest after the stroke: because their momentums will be equal; that is, if each has 2 lbs. of matter, and 10 degrees of celerity, their instantaneous momentums will each be 20.

But if the bodies be perfectly elastic, they will recede from each other with the same velocity with which they meet; because action and re-action are equal.

OF NON-ELASTICITY IN IMPINGING BODIES.

1. If two columns of matter in motion, meeting each other, and equal in non-elasticity, quantity and velocity, they will meet and destroy each other's motion, and remain at rest, provided none of their parts separate.

2. But if one is elastic, and the other non-elastic, they will meet, and one will give way by battering up, and both will move a little further; that is, half the distance that one shortens.

Art. 9.

OF FALLING BODIES.

Bodies descending freely by their gravity, in vacuo, or in an unresisting medium, are subject to the following laws:

1st. They are equally accelerated.

2d. Their velocity is always in proportion to the time of their fall, and the time is as the square root of the distance fallen.

3d. The spaces through which they pass, are as the squares of the times or velocities. Therefore,

4th. Their velocities are as the square root of the space descended through; and their force to produce effects, as their distances fallen directly.

5th. The space passed through the first second is very nearly 16,2 feet, and the velocity acquired at the lowest point, is 32,4 feet per second.

6th. A body will pass through twice the space, in a horizontal direction, with the last acquired velocity of the descending body, in the same time its fall requires.

7th. The total sum of the effective impulse acting on them to give them velocity, is in direct proportion to the space descended through; and their velocity being as the square root of the space descended through, or, which is the same, as the square root of the total impulse, therefore,

8th. Their momentums, or force to produce effects are as the squares of their velocieties, or directly as their distances fallen through; and the times expended in producing the effects, are as the square root of the distances fallen through.

9th. The resistance they meet with in any given time, in passing through a resisting medium, is as their surfaces, and as the cubes of their velocities.—(See table on falling bodies, page 70.)

Art. 10.

OF BODIES DESCENDING INCLINED PLANES AND CURVED SURFACES.

Bodies descending inclined planes and curved surfaces, are subject to the following laws:

1. They are equally accelerated, because their motion is the effect of gravity.

2. The force of gravity propelling a body to descend an inclined plane, is to the absolute gravity of the body, as the height of the plane is to its length.

3. The spaces descended through are as the squares of the times.

4. The times in which the different planes are passed over, are as their lengths respectively.

5. The velocity acquired in descending such planes in the lowest points are all equal.

6. The times and velocities of bodies descending through such planes alike inclined to the horizon, are as the square roots of their lengths.

7. Their velocities, in all cases, are as the square root of their perpendicular descent.

Art. 11.

OF THE MOTION OF PROJECTILES.

A projectile is a body thrown or projected in any direction; such as a stone from the hand, water spouting from any vessel, a ball from a cannon, &c.

Every projectile is acted upon by two forces, viz. the impulse and gravity.

By the impulse, or projectile force, the body will pass over equal distances in equal times, by 1st, general law of motion, Art. 7, and by gravity, it descends through the given spaces, which are as the squares of the times, by 3d law of falling bodies—Art. 9. Therefore, by these forces compounded, the body will describe a curve, called a parabola; and this will be the case in all except perpendicular directions: the curve will vary with the elevation, yet it will be still what is called a parabola.

If the body is projected at an angle of 45 degrees elevation, it will be thrown to the greatest horizontal distance possible; and if projected with double velocity, it will describe a quadruple range.

Art. 12.

OF CIRCULAR MOTION AND CENTRAL FORCES.

If a body be suspended by a string, and caused to move round a centre, that tendency which it has to fly from the centre is called the centrifugal force;—and the action upon a body which constantly solicits it towards a centre, is called the centripital force.—This is represented by the string, which keeps the body in the circle. Speaking of these two forces indefinitely, they are called central forces. The particular laws of this species of motion, are,

1. Equal bodies, describing equal circles, in equal circles, in equal times, have equal forces.

2. Unequal bodies, describing equal circles in unequal times, their central forces are as their quantities of matter multiplied into their velocities.

3. Equal bodies describing equal circles in equal times, their velocities and central forces are as their distances from their centres of motion, or as the radii of their circles.

4. Unequal bodies, describing unequal circles in equal times, their central forces are as their quantities of matter multiplied into their distances from their centres, or the radii of their circles.

5. Equal bodies describing equal circles in unequal times, their central forces are as the squares of their velocities; or in other words, a double velocity generates a quadruple central force; therefore,

6. Unequal bodies describing equal circles in unequal times, their central forces are as their quantities multiplied into their velocities.

7. Equal bodies describing unequal circles with equal celerities, their central forces are inversely as their distances from their centres of motion, or the radii of their circles.

8. Equal bodies describing unequal circles, having their central forces equal; their periodical times are as the square roots of their distances.

9. Therefore the squares of the periodical times are proportional to the cubes of their distanees when neither the periodical times nor the celerities are given. In that case,

10. The central forces are as the squares of the distances, inversely.

Art. 13.

OF THE CENTRES OF MAGNITUDE, MOTION AND GRAVITY.

The centre of magnitude is that point which is equally distant from all the external parts of a body.

2. The centre of motion is that point which remains at rest, while all other parts of the body move round it.

The centre of gravity of bodies is of great consequence to be well understood, it being the principle of much mechanical motion; it possesses the following particular properties:

1. If a body is suspended on this point, as its centre of motion, it will remain at rest in any position.

2. If a body is suspended on any other point, than its centre of gravity, it can rest only in such position, that a right line drawn from the centre of the earth, through the centre of gravity, will intersect the point of suspension.

3. When this point is supported, the whole body is kept from falling.

4. When this point is at liberty to descend in a right line, the whole body will fall.

5. The centre of gravity of all homegeneal bodies, as squares, circles, spheres, &c. is the middle point in a line connecting any two opposite points or angles.

6. In a triangle, it is a right line drawn from any angle to bisect the opposite side, and at the distance of one third of its length from the side besected.

7. In a hollow cone, it is in a right line, passing

from the apex to the centre of the base, and at the distance of one third of the side from the base.

Art. 14.

Of the Mechanical Powers.

Having now premised and considered all that is necessary for the better understanding those machines called mechanical powers, we come to treat of them, and they are six in number, viz.

The Lever, the Pulley, the Wheel and Axle, the Inclined Plane, the Wedge and the Screw.

They are called Mechanical Powers, because they increase our power of raising or moving heavy bodies. Although they are six in number, yet they are all governed by one simple principle, which I shall call the First General Law of Mechanical Powers; which is this, viz. the momentums of the power and weight are always equal, when the engine is in equilibrio.

Momentum, here means the product of the weight of the body multiplied into the distance it moves;—that is, the power multiplied into its distance moved, or into its distance from the centre of motion, or into its velocity, is equal to the weight multiplied into its distance moved, or into its distance from the centre of motion, or into its velocity; or the power multiplied into its perpendicular descent, is equal to the weight multiplied into its perpendicular ascent.

The Second General Law of Mechanical Powers, is,—the power of the engine, and velocity of the weight moved, are always in the inverse proportion to each other; that is, the greater the velocity of the weight moved, the less it must be; and the less the velocity the greater the weight may be; and that universally in all cases.

The Third General Law is,

Part of the original power is always lost, in overcoming friction, inertia, &c.—but no power can be gained by engines, when time is considered in the calculation.

In the theory of this science, we suppose all planes to be perfectly smooth and even, levers to have no weight, cords to be perfectly pliable, and machines to have no friction: in short, all imperfections are to be laid aside, until the theory is established, and then proper allowances are to be made.

Art. 15.

Of the Lever.

A bar of iron, of wood, or of any other inflexible material, one part of which is supported by a fulcrum or prop, and all other parts turn or move on that fulcrum, as their centre of motion is called a lever;—when the lever is extended on each side of the fulcrum the extensions are called its arms; the velocity or motion of every part of these arms, is directly as its distance from the centre of motion, by 3d law of circular motion.

With respect to the lever, when in equilibrium,—Observe the following laws:

1. The power and weight are to each other, inversely as their distances from the fulcrum or centre of motion.

2. The power is to the weight as the distance the weight moves, is to the distance the power moves respectively.

3. The power is to the weight as the perpendicular ascent of the weight is to the perpendicular descent of the power.

4. Their velocities are as the distances from their centre of motion, by 3d law of circular motion.

These simple laws hold universally true, in all mechanical powers or engines; therefore it is easy (from these simple principles) to compute the power of any engine, either simple or compound; for it is only to find how much swifter the power moves than the weight, or how much further it moves in the same time; and so much is the power (and time of producing it) increased by the help of the engine,

Art. 16.

There are four kinds of Levers.

1. The most common kind, where the prop is placed between the weight and power, but generally nearest the weight, as otherwise, there will be no gain of power.

2. When the prop is at one end, and the power at the other, and the weight between them.

3. When the prop is at one end, the weight at the other, and the power applied between them.

4. The bended lever which differs only in form, but not properties, from the others.

Those of the first and second kind, have the same properties and powers, and produce real mechanical advantage, because they increase the power; but the third kind produces a decrease of power, and is only used to increase velocity, as in clocks, watches and mills, where the first mover is slow, and the velocity is increased by the greasing of the wheels.

The levers which nature employs in the machinery of the human frame are of the third kind; for when we lift a weight by the hand, the muscle that exerts the force to raise the weight, is fastened at about one tenth of the distance from the elbow to the hand, and must exert a force ten times as great as the weight raised; therefore he that can lift 56 lbs. with his arm at a right angle at the elbow, exerts a force equal to 560 lbs. by the muscles of his arm.

Art. 17.

COMPOUND LEVER.

Several levers may be applied to act one upon another. The power of these levers, united to act upon a weight, is found by the following rule, which will hold universally true in any number of levers united, or wheels, (which operate on the same principle) acting upon one another.

Rule.—1st. Multiply the power into the length of all the driving levers successively, and note the product.

2d. Then multiply all the leading levers into one another successively, and note the product.

3d. Divide the first product by the last, and the quotient will be the weight that will hold the machine in equilibrio.

On this principle is founded all the rules for calculating the power of motion of wheels in mills, &c.

Art. 18.

Of the Pulley.

The pulley is a mechanical power well known.—One pulley, if it be moveable with the weight, doubles the power, because each rope sustains half the weight.

If two or more pulleys be joined together in the common way, then the easiest way of computing their power is, to count the number of ropes that join to the lower or moveable block, and so many times is the power increased; because all these ropes have to be shortened, and all run into one rope (called the fall) to which the moving power is applied. If there be 4 ropes the power is increased four fold.

Art. 19.

Of the Wheel and Axle.

The wheel and axle is a mechanical power, the same as the lever of the first kind; therefore the power is to the weight as the diameter of the axle is to the diameter of the wheel; or the power multiplied into the radius of the wheel is equal to the the weight multiplied into the radius of the axle, when this engine is in equilibrium.

Art. 20.

OF THE INCLINED PLANE.

The inclined plane is the fourth mechanical power; and in this the power is to the weight as the perpendicular height of the plane is to its length. This is of use in rolling heavy bodies, such as barrells,—hogsheads, &c. into wheel carriages, &c. and for letting them down again. If the height of the plane be half its length, then half the force will roll the body up the plane, that would lift it perpendicularly.

Art. 21.

OF THE WEDGE.

The wedge is only an inclined plane. Whence, in the common form of it, the power applied will be the resistance to be overcome, as the thickness of the wedge is to the length thereof. This is a very great mechanical power, and may be said to excel all the rest; because with it we can effect what we cannot with any other in the same time, and its power I think may be computed in the following manner.

If the wedge be 12 inches long and 2 inches thick, then the power to hold it in equilibrio is as 1 to balance 12 resistance; that is, 12 resistance pressing on each side of the wedge, and when struck with a mallet, the whole force of the gravity of the mallet, added to the whole force of the agent exerted in the stroke, is communicated to the wedge in the time it continues to move: and this force, to produce effect, is as the square of the velocity with which the mallet strikes, multiplied into its weight; therefore, the mallet should not be too large, because it may be too heavy for the workman's strength, and will meet too much resistance from the air, so that it will lose more by lessening the velocity,—than it will gain by its weight. Suppose a mallet of 10 lbs. strike with 5 velocity, its effective momentum is 250; but if it strike with 10 velocity, then its effective momentum is 1000. The effects produced by the strokes will be as 250 to 1000; and all the force of each stroke, except what may be destroyed by the friction of the wedge, is added in the wedge, until the sum of these forces amount to more than the resistance of the body to be split, which therefore must give way; but when the wedge does not move, the whole force is destroyed by the friction; therefore the less the inclination of the sides of a wedge, the greater resistance we can overcome by it, because it will be easier moved by the stroke.

Art. 22.

OF THE SCREW.

The screw is the last mentioned mechanical power, and is a circular inclined plane, (which will appear by wrapping a paper cut in the form of an inclined plane, round a cylinder) and the lever of the first kind combined (the lever being applied to force the weight upon the inclined plane;) this is a great mechanical power, and is used both for pressure and raising great weights. The power applied is to the weight it will raise as the distance through which the weight moves is to the distance through which the power moves; that is, as the distance of the threads of the screw is to the circle the power describes, so is the power to the weight it will raise.—If the distance of the thread be half an inch, and the lever be 15 inches radius, and the power applied be 10 lbs. then the power will describe a circle of 94 inches, while the weight rises half an inch; then, as half an inch is to 94 inches, so is 10 lbs. to 1880 lbs. the weight the engine would raise with 10 lbs. power. But this is supposing the screw to have no friction, of which it has a great deal.

Art. 23.

OF THE FLY-WHEEL AND ITS USE.

Before I dismiss the subject of mechanical powers, I shall take notice of the fly-wheel, the use of which is to regulate the motion of engines, and which should be of cast metal, of a circular form, that it may not meet with much resistance from the air.

Many have taken this wheel for an increaser of power, whereas it is, in reality, a considerable destroyer of it; which appears evident, when we consider that it has no motion of its own, but receives all its motion from the first mover, and as the friction of the gudgeons and resistance of the air to be overcome, it cannot be done without some power:—yet this wheel is of great use in many cases, viz.

1st. For regulating the power, where it is irregularly applied, such as the treadle or crank moved by the foot or hand; as in spinning wheels, turning-lathes, flax-mills, or where steam is applied, by a crank, to produce a circular motion.

2d. Where the resistance is irregular, or by jerks, as in saw-mills, slitting-mills, &c. the fly-wheel, by its inertia, regulates the motion; because, if it be very heavy, it will require a great many little shocks, or impulses of power to give it a considerable velocity; and it will require as many equal shocks to resist or destroy the velocity it has acquired, by axiom 3, Art. 1.

While a rolling or slitting-mill is running empty, the force of the water is employed in generating momentum in the fly-wheel [a heavy water-wheel will have the same effect,] which force summed up in the fly, will be sufficient to continue the motion, without much abatement, while the sheet of metal is running between the rollers; whereas, had the force of the water been lost while the mill was empty, its motion might be destroyed before the metal passed through the rollers. Where water is scarce, its effect may be so far aided by a fly-wheel, as to overcome a resistance to which the direct force of the water is unequal.

Art. 24.

OF SPOUTING FLUIDS.

Spouting fluids observe the following laws.

1. Their velocities and powers, under equal pressures, or equal perpendicular heights, and equal apertures, are equal in all cases.

2. Their velocities under different pressures,—or perpendicular heights, are as the square roots of those pressures or heights; and their perpendicular heights or pressures are as the squares of their velocities.

3. Their quantities expended through equal apertures, in equal times, under unequal pressures, are as their velocities simply.

4. Their pressures or heights being the same, their effects are as their quantities expended.

5. Their quantities expended being the same, their effects are as their pressure, or height of their head directly.

6. Their instant forces with equal apertures, are as the squares of their velocities, or as the height of their heads directly.

7. Their effects are as their quantities, multiplied into the squares of their velocities.

8. Therefore their effects or powers with equal operations are as the cubes of their velocities.

9. Their velocity under any head is equal to the velocity that a heavy body would acquire in falling from the same height.

10. Their velocity is such under any head or height as will pass over a distance equal to twice the height of the head, in a horizontal direction, in the time that a heavy body falls the distance of the height of the head.

11. Their action and re-action are equal.

12. They being non-elastic, communicate only half their real force by impulse, in striking obstacles; but by their gravity produce effects equal to elastic or solid bodies.

To contrive a proper Machine, that shall move a given weight with a given power, or with a given quantity of force, that shall overcome any other given resistance.

[From Emerson's Principles of Mechanics.]

If the given power is not able to overcome the given resistance, when directly applied, that is, when the power applied is less than the weight or resistance given, then the thing is to be performed by the help of a machine made with levers, wheels, pullies, screws, &c. so adjusted that when the weight and power are put in motion on the machine, the velocity of the power may be at least so much greater than that of the weight, as the weight and friction of the machine taken together is greater than the power;—for on this principle depends the mechanism or contrivance of mechanical engines, used to draw or raise heavy bodies or overcome any other force.—The whole design of these being to give such a velocity to the power in respect of the weight, or that the momentnm of the power may exceed the momentum of the weight;—for if the machines are so contrived that the velocities of the agent and resistance are reciprocally as their forces, the agent will just sustain the resistance; but with a greater of velocity, will overcome it, so that if the excess of velocity in the power is so great as to overcome all that resistance which commonly arises from or attraction of contiguous bodies, as they slide by one another, or from the cohesion of bodies that are to be separated, or from the weight of bodies to be raised, the excess of the force remaining, after all these resistances are overcome, will produce an acceleration of motion proportional thereto, as well in the parts of the machine as in the resisting body. Now how a machine may be contrived to perform this to the best advantage, will appear from the following rules.

1. Having assigned the proportion of your power, and the weight to be raised, the next thing is to consider how to combine levers, wheels, pulleys, &c. so that working together, they may be able to give a velocity to the power, which shall be to that of the weight, something greater than that of the proportion of the weight to the power, this done, you must estimate your quantity of friction by the last proportion; and if the velocity of the power be to that of the weight, still in a greater proportion than the weight, then the weight and friction taken together is to the power, then your machine will be able to raise the weight, and note this proportion must be so much greater as you would have your engine work faster.

2. But the proportion of the velocity of the power and weight must not be made too great neither; for it is a fault to give a machine too much power, as well as too little, for if the power can raise the weight and overcome the resistance and the engine perform its proper office in a convenient time, and works well it is sufficient for the end proposed. And it is in vain to make more additions to the engine, to increase the power any further; for that would be not only a useless expense, but the engine would lose time in working.

3. As to the power applied to work the engine, it may be either a living power, as a man, a horse, &c. or an artificial power, as a spring, weights, &c. or a natural power, as wind, water, fire, &c. When the quantity of the power is known, it matters not, as to the effect, what kind of power it is, for the same quantity of any sort will produce the same effect;—and different sorts of power may be applied in an equal quantity, a great variety of ways.

The most easy power applied to a machine is weight, if it be capable of effecting the thing designed; if not, then wind, water, &c. if that can conveniently be had without much expense. A spring is also a convenient moving power for several machines, but it never acts equally, as a weight does—but is stronger, when much bent than when but little bent, and that in proportion to the degree of bending, or the distance it is forced to. But springs grow weaker by often bending, or remaining long bent;—yet they recover part of their strength by lying unbent.

The natural powers, wind, and water, may be applied with vast advantage to the working of great engines, when managed with skill and judgment, the due application of these has much abridged the labor of men; for there is scarce any labor to be performed but an ingenious artificer can tell how to apply these powers to execute his design, and answer his purpose. For any constant motion being given, it may by due application be made to produce any other motion we desire. Therefore, these powers are the most easy and useful, and of the greatest benefit to mankind; besides, they cost nothing nor require any repetition or renewing, like a weight or a spring—which requires to be wound up. When these cannot be had or cannot serve our end, we have recourse to some living power, as men, horses, &c.

4. Men apply their strength several ways;—in working a machine, a man of ordinary strength turning a roller by a handle, can act for a whole day against a resistance equal to 30 pounds weight; and if he work ten hours in a day, he will raise a weight of 30 pounds 3½ feet in a second; or if the weight be greater, he will raise it so much less in proportion; but a man may act for a small time, against a resistance of 50 pounds or more.

If two men work at a windlass or roller, they can more easily draw up 70 pounds than one man can 30 pounds, provided the elbow of one of the handles be at a right angle to that of the other, and with a fly or heavy wheel applied to it, a man may do one third part more work, and for a little while act with a force, or overcome a continual resistance of 80 lbs. and work a whole day when the resistance is but 40 pounds. Men used to carrying, such as porters, will carry, some 150 lbs. others 200 or 250 lbs. according to their strength. A man can draw about 70 or 80 lbs. horizontally, for he can apply about half of his weight. If the weight of a man be 140 lbs. he can act with no greater a force in thrusting horizontally at the height of his shoulders, than 27 lbs.

As to horses, a horse is, generally speaking,—as strong as five men. A horse will carry 240 or 270 lbs. A horse draws to greatest advantage when the line of direction is a little elevated above the horizon, and the power acts against his breast: and can draw 200 lbs. for 8 hours in a day, at 2½ miles in an hour. If he draw 240 lbs. he can work but 6 hours, and not quite so fast. And in both cases, if he carry some weight, he will draw better than if he carried none. And this is the weight a horse is supposed to be able to draw, over a pulley, out of a well. In a cart a horse can draw 1000 lbs.

The most force a horse can exert is when he draws something above a horizontal position.

The worst way of applying the strength of a horse, is to make him carry or draw up hill, and 3 men in a steep hill, carrying each 100 lbs. will climb up faster than a horse with 300 lbs.

Though a horse may draw in a round walk of 18 feet diameter, yet such a walk should not be less than 25 or 30 feet diameter.

5. Every machine ought to be made of as few parts, and those as simple as possible, to answer its purpose, not only because the expense of making and repairing will be less, but it will be less liable to get

out of order, and it is needless to do a thing with many when it can be done with fewer parts.

6. If a weight is to be raised but a very little distance the lever is the most simple, easy, and ready machine. Or, if the weight be very great, the common screw is the most proper. But if the weight is to be raised a great way, the wheel or axle is a proper power, and blocks and pulleys are easier still, and the same may be done by the help of the perpetual screw.

Great wheels, to be wrought by men or cattle, are of most use and convenience when their axles are perpendicular to the horizon; but if by water, &c. then it is best to have their axles horizontal.

7. As to the combination of simple machines together, to make a compound one, though the lever, when simple, cannot raise a weight to any great height, and in this case is of like service, yet it is of great service when accompanied with others. Thus the spokes of a great wheel are all levers, perpetually acting; and a beam fixed to the axis to draw the wheel about by men or horses, is a lever. The lever also may be combined with the screw, but not conveniently with pullies or with the wedge. The wheel and axle is combined with great advantage, with pullies. The screw is not well combined with pullies, but the perpetual screw combined with the wheel, is very serviceable. The wedge cannot be combined with any other mechanical power, and it only performs its effect by percussion, but this force may be increased by engines.

Pullies may be combined with pullies, and wheels with wheels; therefore, if any single wheel would be too large and take up too much room, it may be divided into two or three more wheels; and trundles or wheels and pinions, as in clock-work, so as to have the same power and perform the same effect. In wheels with teeth, the number of teeth that play together in two wheels, ought to be prime to each other, that the same teeth may not meet at every revolution; for when different teeth meet, they by degrees wear themselves into a proper figure; therefore they should be contrived to meet as seldom as possible.

8. The strength of every part of the machine ought to be made proportional to the stress it is to bear; and therefore let every lever be made as much stronger as its length and the weight it is to support is greater, and let its strength diminish proportionally from the fulcrum, or point. When the greatest stress is to each end, the axles of wheels and pullies must be so much stronger, as they are to bear greater weight.

The teeth of wheels, and wheels themselves, which act with greater force, must be proportionally stronger; and in any combination of wheels and axles—make their strength diminish gradually, from the weight to the power, so that the strength of every part be reciprocally as the velocity it has. The strength of ropes must be according to their tension, and that is as the square of their diameters. And in general, whatever parts a machine is composed of—the strength of every part of it must be adjusted to the stress upon it. Therefore, in square beams, the cubes of the diameters must be made proportional to the stress they bear, and let no part be stronger or bigger than is necessary for the stress upon it, not only for the ease and well going of the machine, but for the diminishing the friction. For all superfluous matter, in any part of it, is nothing but a dead weight upon the machine, and serves for nothing but to clog its motion, and he is by no means a perfect mechanic that does not only adjust the strength to the stress, but also contrive all the parts to last equally well—that the whole machine may fail together.

9. To avoid friction as much as possible, the machine ought not to have any unnecessary motions, or useless parts, for a multiplicity of parts, by their weight and motion, increase the friction. The diameters of the wheels and pullies ought to be large, and the diameters of the arbors or spindles they run on, as small as can be consistent with their strength.—All ropes and cords must be as pliable as possible, and for that end are rubbed in tar or grease; the teeth of wheels must be made to fit and fill up the openings, and cut in the form of an epicycloid, all the axles, where the motion is, and all teeth, where they work, and all parts that in working, rub upon one another, must be made smoother, and when the machine goes must be oiled or greased; if a joint is to go pretty stiff and steady, rub a little grease upon it. The axis of a wheel may have its friction diminished by causing it to run on two rollers turning round with it on two centres. Likewise, in lanterns and trundles, the rounds may be made to turn about instead of being fixed.

In all machines with wheels the axles or spindles ought not to shake, which they will do if they be too short; and their ends ought just to fill their holes.—When the teeth of wheels are much worn away, it makes that wheel move irregularly about, increases the friction, and requires more force, and may cause the teeth of two wheels to run foul upon one another, and to stop their motion, and endanger breaking their teeth;—to prevent this proper care should be taken to dress the teeth and keep them to their proper figure.

10. When any motion is to be long continued, contrive the power to move or act always one way, if it can be done, for this is better and easier performed than when the motion is interrupted, and the power is forced to move first one way and then the other, be-

cause every new change of motion, requires a new additional force to effect it. Besides, a body in motion cannot suddenly receive a contrary motion without great violence, and the moving any part of the machine contrarily, turns, and sudden jerks, tend to injure the machine.

11. In a machine that moves always one way, endeavor to have the motion uniform.

12. But when the nature of the thing requires that a motion is to be suddenly stopped, to prevent any damage or violence to the engine by a sudden jolt, let the force act against a spring or beam of wood, which may supply the place of a spring.

13. In regard to the size of the machine, let it be made large as it can conveniently;—the greater the machine the exacter it will work and perform all its motions the better, for there will always be some errors in the making, as well as in the materials, and consequently in the working of the machine. The resistance of the medium in some machines has a sensible effect, but all these mechanical errors bear a less proportion to the motion of the machine in great machines than in little ones, being nearly reciprocally as their diameters, supposing they are made of the same matter, and with the same accuracy;—therefore in a small machine they are more sensible, but in a great one almost vanish. Therefore great machines will answer better than smaller, in all respects except in strength, for the greater the machine the weaker it is, and less able to resist any violence.

14. For the engines that go by water, it is necessary to measure the velocity and force of the water, to get the velocity, drop in pieces of sticks, &c. and observe how fast they move in a second, or any given time. But if it flow through a hole in a reservoir, or a standing receptacle of water, the velocity will be found from the depth of the hole below the surface;

when you have but a small quantity of water, you must contrive it to fall as high as you can, to use it a greater length of time, upon the engine.

15. If water is to be conveyed through pipes to a great distance, and the descent be but small, so much larger pipes must be used,—because the water will come slow, and these pipes ought not to be made straighter in some places than in others; for the quantity of water conveyed through them depends upon the bigness of the bore at the straightest place.

Pipes of conduct coming directly from an engine should be made of iron, with flanches at the ends, to screw together, with lead between, or else of wood; for lead pipes will bulge out at every stroke of the engine, and burst; but pipes next a jet must be lead, pipes should not turn off at an angle, but gradually in a curve. Pipes of elm will last 20 or 30 years, in the ground, but they must be laid so deep that the frost may not reach them, or else the water must be let out, otherwise the frost will split them. The thickness of any pipe must be as the diameter of the bore, and also as the depth from the spring; for a lead pipe of 6 inches bore and 60 or 70 feet high, the thickness must be half an inch; and in wooden pipes 2 inches.

Water should not be drawn through pipes faster than four feet per second, by reason of the friction of the tubes, nor should it be much wire drawn, that is, squeezed through smaller pipes, for that creates a resistance, as the water-way is less in narrow pipes, And in all pump work where water is conveyed thro' pipes to higher places, the bores of the pipes should not be made too straight upwards, for the straighter they are near the top, the less water will be discharged; nor should the pipe that brings the water into the pump be too straight, for the same reason—the wider these are the easier the pump works.

When pipes are wind bound, that is, when air is lodged in them, that the water can hardly pass, it must be discharged thus: Going from the spring till you come to the first rising of the ground, dig it open till the pipe is laid bare, then, with a nail driven into it at the highest part, or rather a little beyond, make a hole in the top and all the air will blow out at the hole, and when the water comes, batter up the hole again. Do the same at every eminence, and all the air will be discharged. If the water runs fast thro' the pipes, the air will be beyond the eminence; but stopping the water, the air will ascend to the highest part. If air be driven in, at first, along with the water, the nail hole must be left open, or a cock placed there, to open occasionally. Sometimes a small leaden pipe is placed over the other, communicating with it in several places, in which is a cock at top, to open upon occasion.

16. When any work is to be performed by a water-wheel moved by the water running under it, and striking the paddles or laddle-boards, the channel it moves in ought to be something wider than the hole of the adjutage, and so close to the floats on every side as to let little or no water pass; and when past the wheel, to open a little, that the water may spread. It is of no advantage to have a great number of floats, or paddles, for those past the perpendicular are resisted by the back water, and those before it are struck obliquely. The greatest effect that such a wheel can perform, in communicating any motion, is when the paddles of the wheel move with one third the velocity of the water; in which case, the force upon the paddles is $\frac{4}{9}$ only, supposing the absolute force of the water against the paddles, when the wheel stands still, to be 1. So that the utmost motion which the wheel can generate is but $\frac{4}{27}$ of that which the force of the water against the paddles at rest

would produce. This is when the wheel is at the best, but often times far less is done.

Machines to raise water, when well made, seldom lose less than ⅕ the computed quantity of water to be raised. The best contrived engine is scarce ⅕ part better than the worst contrived engine, when they are equally well executed.

A man with the best water engine, cannot raise above one hogshead of water in a minute 10 feet high, to work all day.

17. When a weight is to be raised with a given corporeal power, by means of the wheel and axle, so that the weight may receive the greatest motion possible in a given time, the radius of the wheel and axle and the weight to be raised, ought to be so adjusted that the radius of the axle may be to the radius of the wheel, as ⅖ the power, to the weight to be raised;—or, which comes to the same thing, the velocity gained by the power in descending must be ⅖ of the velocity which would be gained by gravity in the same time. This only holds good when the power is a heavy body, as well as the weight; but does not take place when the power is some immaterial active force, such as that of an elastic medium, the strength of a spring, &c. whose weight is inconsiderable.

18. These principles also are very useful and necessary to be known, where water-works are concerned.

The pressure of the atmosphere upon a square inch is $14\frac{7}{10}$ lbs. avoir. at a medium.

The weight of a column of water equal to the weight of the atmosphere, is 11¼ yards.

A cubic foot of water weighs 62½ lbs. avoir. and contains 6.128 ale gallons.

An ale gallon of water contains 282 inches, and weighs $10\frac{2}{10}$ lbs. avoir.

A tun of water, ale measure, weighs $1\frac{1}{10}$ tun avoir. at 63 gallons the hogshead.

A cylinder of water a yard high, and *d* inches in diameter, contains $\frac{1}{10}$ *dd* ale gallons, and weighs $\frac{1}{40}$ *dd* lbs. avoir.

STANDARDS FOR CALCULATING POWER.

The standard for calculating the power applied to machines has been most naturally derived from a reference to the power of a horse for ordinary labor. The *actual power* of a common horse, from an average of a great number of experiments of the working strength of this animal, has been estimated to be equal to raising 352 cubic feet of water, or 22,000 lbs. one foot high in a minute, working 8 hours per day, and moving at the rate of 2½ miles per hour; or the same result is obtained by supposing a horse to be able to travel for 8 hours every day, at the rate of 2½ miles an hour, or 220 feet per minute, and during this time to raise a weight of 100 lbs. suspended over a pulley. In order however to prevent disappointments in the effective power calculated upon by purchasers of steam engines, Boulton & Watt adopted a much higher standard, equal to *fifty per cent. more than the actual power of an ordinary horse.*

Messrs. Boulton and Watt suppose a horse to be able to raise 32,000 lbs. 1 foot per minute.

Desaguilliers supposes a horse to be able to raise only 27,500 lbs. do.

Smeaton, again, computes a horse power at 22,916 lbs. do.—which is about the standard of the actual power of a horse.

This great difference in the estimate of a horse-power may be attributable in part to the real difference in the strength of this animal. A London dray horse is a gigantic animal, endowed with strength nearly adequate to performing the labor assigned by Boulton & Watt; while other horses, and perhaps an average of them, will not be able to perform more than is assigned by the standard of Mr. Smeaton.— In contracting for steam engines of a certain horse power, it should always be specified which of the above standards are intended to be adopted as a rule for calculation.

Boulton & Watt in calculating the power of their engines, actually allow for a force to act upon the piston of about double the effective force of a horse. The moving power applied to the piston according to their calculation, is equal to raising 44,000 lbs. 1 foot high in a minute, were the weight to be placed directly upon the top of the piston. The actual effective power available is, however, reduced by friction, and the force consumed in moving the air pump, and other parts of the engines, to 32,000 lbs. raised one foot high in a minute, as above stated. About one third of the power is thus lost, and the atmospheric pressure, although nearly equal to 15 lbs. on each square inch of the piston, gives a power available by means of the crank, equal to only 10 lbs. on the square inch. A similar loss of power takes place in regard to the weight of water applied to the buckets of the water wheel, which is capable of raising but two thirds of the quantity of water that operates upon it to the level from which it falls.

The power of an able-bodied man, working ordinary hours, is calculated from the results of various experiments made by Smeaton and others, to be equal to raising 60 cubic feet of water (weighing 62½ lbs. each) one foot high per minute, equal to ⅙ of the horse power, by Smeaton's standard, and less than ⅛ of a horse power, according to Boulton & Watt's standard.

The following has been proved by numerous experiments, made in England and Scotland, to be the effective result of a one horse power applied to moving cotton machinery. The standard of Boulton and

Watt, although it represents a much higher power than that of an ordinary horse, from having been first introduced into use has been generally adopted. It is of more importance to have one determinate rule for the measure of force, that will, under the most unfavorable circumstances of the condition of a machine, give a result equal to the power of a horse,—than to introduce confusion by attempting to establish new and more exact standards.

1 horse power is calculated at a medium
" = to drive 100 throstle spindles, with preparation, for cotton yarn twist.
" = " 500 spindles, with preparation, for mule yarn, No. 48.
" = " 1000 spindles do. for do. No. 110, and for intermediate Nos. of yarn, in the same proportion.
" = " 12 Power Looms, with preparation.

It is stated by Smeaton, that a strong horse is able to lift by means of a pump, 250 hhds. (63 gallons each) of water, 10 feet high, in one hour, at a maximum. 12 galls. of water weigh 100 lbs. Thus the actual weight of water lifted is at the rate of 22,000 lbs. raised one foot per minute. The standard of a horse power, as above stated, is 32,000 lbs. raised 1 foot high per minute.

At Lowell, (Ms.) 24 cubic feet of water per second, with a fall of 30 feet, has been found sufficient to operate 4000 spindles, with all the preparatory machinery, for spinning cotton yarn, about No. 30, together with the looms necessary for weaving the same. The spindles in use at that place are all of the sort called "dead spindles," requiring rather more power to operate them than the common English throstle spindles alluded to in the above table. The difference of power required for the dead spindle is probably as 4000 to 4300, or 4400. Calling 4000 dead spindles equal to 4400 throstle spindles, the power required to operate them, together with the necessary preparatory machinery, will be

Equal to that of - 44 horses.
144 Looms (at 12 looms to the horse) 12 do.

Horse power, 56.

A calculation of the efficient power of the quantity of water used (24 cubic feet per second, with a fall of 30 feet,) is here given, to show that the estimates of the power required to operate an equal amount of machinery will nearly coincide with that actually imparted by the water wheels.

24 cubic feet of water per second, is equal to 1,440 cubic feet per minute.

1440×62½ (the weight in lbs. of each cubic foot of water) gives 90,000 lbs.×30 feet, the fall of water, =2,700,000 lbs. descending one foot per minute. Deduct ⅓ for the loss of power by friction and otherwise, in applying the weight of water to the wheel, &c. and dividing the remainder by 32,000 lbs. (Boulton & Watt's standard) gives 56¼ horse power.

At the Hamilton mills, in Lowell, where the fall of water is only about 12 feet, the same quantity of machinery is operated by using 60 cubic feet of water per second.

The 56¼ horse power required for one of the above mills would be sufficient to put in motion 56000 *mule spindles* with preparation for spinning yarn as fine as No. 110, or above 10,000 mule spindles for spinning yarn for warp and weft as fine as No. 48, together with 400 looms to weave the same. It is partly in consequence of the great expense of power to operate throstle spindles, that the throstle twist commands a higher relative price in Manchester than yarn of the same fineness spun upon mules. One of the most extensive cotton mills in Manchester, owned by Mr. Murray, contains 90,000 mule spindles—which are operated for spinning yarn, from 200 to 250 hanks to the pound, by two steam engines, rated at less than 80 horse power.

The calculations respecting the power of a horse it has been observed, are rendered vague and uncertain by considering the power of the animal as a constant quantity, without making due allowance for the velocity with which he may move. An ordinary horse commonly exerts a force of traction equal to 150 lbs. This is reduced to less than one half when he travels four miles an hour;—to one ninth part when he travels 8 miles an hour, and at 12 miles an hour his whole strength is barely sufficient to carry forward his own weight; and his power of draught or traction nearly ceases when he travels with a speed of 14 or 15 miles an hour.

According to the variations of speed, Professor Leslie supposes that a horse moving only 1 mile per hour, might pull with a force of 181 lbs. at 2 miles per hour with a force of about 150 lbs. at 3 miles with 120 lbs. at 4 miles with 96 lbs. At a dead pull, when the exertion is continued only for a few moments, a horse might exert a power of 5 or 600 lbs. or more.

A horse, it is stated, can in general carry no more up a steep hill than three men can carry. This is the most unfavorable application of the strength of a horse, for if the hill be steep, 3 men, each carrying a burden of 100 lbs. will ascend faster than a horse loaded with 300 lbs. A strong horse, by an effort—may succeed in drawing 2000 lbs. up a steep hill,—provided the ascent is short and the road good. The form of a horse is most favorable for draught on a horizontal plane. The forward part of his body is brought to operate by its gravity, as the power upon the bended lever, the hinder feet serving as the pivot or fulcrum. For this reason a horse is able to exert as much power in drawing a canal boat as 7 or 8 men.

The most favorable posture for the exertion of the muscular strength of man is the act of rowing a boat, in which position his power is applied on nearly the same principles as stated before of the horse, the whole weight of his body being extended nearly horizontally and operating by its gravity with leverage power.

Horse power is usually applied to mechanical purposes by means of a lever connected with a perpendicular shaft, which is turned by the horse as he traverses a circular walk or path.

The diameter for the walk of a horse mill should not be less than 25 feet; otherwise the line of the direction of the draught forms an acute angle with the lever, and not a right angle with it, as should be the case in order to apply the power with full effect. The bar to which the traces are attached should be secured so as to swivle, and favor the motion of the animal, without producing an unequal resistance upon his shoulders. The geering must be also calculated to produce the desired motions when the horse proceeds at the rate of 2½ miles per hour.

ON THE EQUAL ACTION AND REACTION OF MOTION AND FORCES.

By Dr. Arnott.

"There is no motion or action in the universe, without a a concomitant and opposite action of equal amount."

This truth has otherwise been expressed—"action and reaction are equal and contrary." It is clear that if no action or movement takes place on earth but in consequence of either attraction or repulsion; and this has now been shewn—there must always be two objects or masses concerned, and each must be attracted or repelled just as much as the other, although one will have less velocity than the other, as it may be itself greater, or fixed to another mass.

If a man in one boat pull at a rope attached to another, the two boats will approach. If they be of equal size and load, they will both move at the same rate, in whichever of the boats the man may be;—and if there be a difference in the sizes, and resistances, there will be a corresponding difference in the velocities, the smaller boat moving the fastest.

A magnet and a piece of iron attract each other equally, whatever disproportion there is between the masses. If either be balanced in a scale, and the other be brought within a certain distance beneath it, the very same counterpoise will be required to prevent their approach, whichever be in the scale. If the two were hanging near each other as pendulums, they would approach and meet; but the little one would perform more than half of the journey.

A man in a boat pulling a rope attached to a large ship, seems only to move the boat: but he really moves the ship a little, for, supposing the resistance of the ship to be just a thousand times greater than that of the boat, a thousand men in 1000 boats, pulling simultaneously in the same manner, would make the ship meet them half way.

A pound of lead and the earth attract each other with equal force, but that force makes the lead approach sixteen feet in a second towards the earth,—while the contrary motion of the earth is of course as much less than this as the earth is weightier than one pound—and is therefore unnoticed. Speaking strictly, it is true, that even a feather falling, lifts the earth towards it, and that a man jumping kicks the earth away.

A spring unbending between two equal bodies—throws them off with equal velocity; if between bodies of different magnitudes the velocity is greater in the smaller body, and in proportion to the smallness.

On firing a cannon, the gun recoils with even more motion or momentum in it than the ball has, for it suffers the reaction of the expelled gun-powder as well as of the ball; but the momentum in the gun being diffused through a greater mass, the velocity is small, and easily checked.

In the art of projectiles, it has lately been proposed, as promising a great saving of weight in the field or on ship board, besides other advantages, that instead of shooting round bullets from a great barrel or cannon, as at present, the bullets should be made somewhat of barrel-shape, or should have a small barrel as a tail, and should be shot away from a strong fixed spindle, or close-fitting ramrod, which would then constitute the piece of ordnance. Such a projectile, for the reason stated in the last paragraph, receives more momentum from a given quantity of gunpowder than a common ball does. The experiment has been tried by the ingenious proposer, Mr. Levier, with satisfactory result.

The recoil of a light fowling piece will hurt the shoulder, if the piece be not held close to it.

A ship in chase, by firing her bow guns, retards her motion; by firing from her stern she quickens it.

A ship firing a broadside, heels or inclines to the opposite side.

A vessel of water suspended by a cord, hangs perpendicularly: but if a hole be opened in one side,—so as to allow the water to jet out there, the vessel will be pushed to the other side by the reaction of the jet, and will so remain while it flows. If the hole be oblique, the vessel will turn round constantly.

A vessel of water placed upon a floating piece of plank, and allowed to throw out a jet, as in the last case, moves the plank in the opposite direction.

A steamboat may be driven by making the engine pump or squirt water from the stern, instead of making it, as usual, move paddle-wheels. There is a loss of power however in this mode of applying it.

A man floating in a small boat, and blowing strongly with a bellows towards the stern, pushes himself onwards with the same force with which the air issues from the bellows pipe.

A sky-rocket ascends, because, after it is lighted, the lower part is always producing a large quantity of aeriform fluid, which, in expanding, presses not only on the air below, but also on the rocket above, and thus lifts it. The ascent is aided also by the recoil of the rocket from the part of its substance,—which is constantly bursting downwards.

He was a foolish man who thought he had found the means of commanding always a fair wind for his pleasure-boat, by erecting an immense bellows in the stern. The bellows and sails acted against each other, and there was no motion: indeed, in a perfect calm, there would be a little backward motion, because the sail would not catch all the wind from the bellows.

A man supported on a floating plank, by walking towards one end of it gives it a motion in the direction opposite.

A man using an oar, or a steam engine turning paddle-wheels, advances exactly with the force that drives the water astern.

A swimmer pressing the water downwards and backwards with his hands, is sent forwards and upwards with the same force, by the reaction of the water.

And a bird flying is upheld with exactly the force with which it strikes the air in the opposite direction.

A man pushing against the ground with a stick may be considered as compressing a spring between the earth and the end of his stick, which spring is therefore pushing him up as much as he pushes down; and if, at the time, he were balanced in the scale of a weighing beam, he would find that he weighed just as much less as he were pressing with his stick.

Thus an invalid, on a spring plank or chair, who by a trifling downward pressure of his hand on a staff or on a table, causes his body to rise and fall through a great range, and thus obtains the advantage of almost passive exercise, is really lifting himself while he presses downward.

When a child cries, on knocking his head against a table or pane of glass, it is common to tell him, and it is true that he has given as hard a blow as he has received; although his philosophy probably, looking chiefly to results, blames the table for his head hurt, and his head for the glass broken.

The difference of momentum acquired in the fall of one foot or of several is well known: the corresponding intensities of reaction are unpleasantly experienced by a man, who, in sitting down where he supposed a chair to be, unexpectedly reaches the floor.

What motion the wind has given to a ship it has itself lost, that is to say, the ship has reacted on the moving air; as is seen when one vessel is becalmed on the lee of another.

When one billiard ball strikes directly another ball of equal size, it stops, and the second ball proceeds with the whole velocity which the first had—the action which imparts the new motion being equal to the re-action which destroys the old. Although the transference of motion in such a case, seems to be instantaneous, the change is really progressive—and as follows. The approaching ball, at a certain point of time, has just given half its motion to the other equal ball, and if both were of soft clay, they would then proceed together with half the original velocity; but as they are elastic, the touching parts at the moment supposed are compressed like a spring between the balls, and by then expanding, and exerting force equally both ways, they double the velocity of the foremost ball, and destroy altogether the motion of that behind.

If a billiard ball be propelled against the nearest one of a row of balls equal to itself, it comes to rest as in the case last described, while the farthest ball of the row darts off with its velocity—the intermediate balls having each received and transmitted the motion in a twinkling, without appearing themselves to move.

As further illustrative of the truths, that action and re-action are equal and contrary, and that in every case of hard bodies striking each other, they may be regarded as compressing a very small strong spring between them, we may mention, that when any elastic body, as a billiard ball, strikes another body larger than itself, and rebounds, it gives to that other, not only all the motion which it originally possessed, this being done at the moment when it comes to rest,—but an additional quantity, equal to that with which it recoils, owing to the equal action in both directions of the repulsion or spring which causes the recoil.—When the difference of size between the bodies is very great, the returning velocity of the smaller is nearly as great as its advancing motion was, and thus it gives a momentum to the body struck, nearly double of what it originally itself possessed. This phenomenon constitutes the paradoxical case of an effect being greater than its cause, and has led persons imperfectly acquainted with the subject, to seek from the principle a *perpetuum mobile.* A hammer, on rebound ing from an anvil, has given a blow of nearly double the force which it had itself, for the anvil felt its full original force while stopping it, and then, equally with itself, was affected by the repulsion which caused its return.

Many more interesting facts might be adduced as examples of equal action and reaction, but these will suffice.

PHILOSOPHICAL FACTS.

Sound travels 1132 feet in a second, or 13 miles in a minute. The softest whisper flies as fast as the loudest thunder; and no sound produced by artificial means can be heard over 200 miles; but sounds produced by volcanoes, have been heard a much greater distance.

Light goes about 13,000,000 of miles in a minute. A strong wind flies 20 feet in a second. If the distance between us and a cannon when fired, be one mile, we hear the report 24 seconds after we see the flash.

The average quantity of rain that falls in a year, is 35 inches, including snow, which would be 3448 tons, 160 pounds to the acre, or 2,184,175 tons 1400 pounds to the square mile.

ON THE APPLICATION TO THE ARTS, OF SIR H. DAVY'S DISCOVERY, *resulting from his Electro-Chemical Theory.*

[From the Mechanics' Magazine.]

To the Editor.—SIR,—It was supposed by Sir Humphrey Davy, that instead of affinity being a distinct species of attraction, two substances had a tendency to unite only in consequence of their being in opposite states of electricity. This view of affinity suggested to Sir H. a matter of very great importance—a mode of preventing metals from being acted on by oxygen. The metals are electro-positive, and oxygen electro-negative, and this is the reason, according to Davy, of an affinity existing between them. Now, if by any means the metals can be retained in an electro-negative condition, they cannot suffer oxidation, or, in common language, they cannot *rust*.

The importance of some mode of completely preventing oxidation must be evident to all, since the evil effects of oxygen on articles composed of metal are daily witnessed. The substance employed in rendering iron or steel electro-negative is *zinc*. A very small quantity of this metal applied to any article composed of iron or steel, will completely prevent the action of oxygen upon it, whether exposed to air or water. All articles of cutlery whatever, all iron, steel, or copper instruments used by mechanics, (excepting those which are exposed to fire,) all farming utensils—axes, hoes, sickles, scythes, plough-shares, chains, &c. &c. can be effectually prevented from "rusting" by the application of a very small quantity of zinc, soldered to them in any place where it could be the most conveniently done. The expense of the zinc for this purpose is exceedingly trifling.—"A piece of zinc," says Dr. Turner, "as large as a pea, or the head of a small round nail, was found fully adequate to preserve 40 or 50 square inches of copper—and this, wherever it was placed, whether at the top, bottom, or middle of the sheet of copper, or under whatever form it was used."—*Turner's Chemistry, p.* 99, *Am. edition.*

This brilliant discovery of Sir H. Davy's, the result of his Electro-Chemical Theory, was first applied to the copper sheathings of ships, which all know are very expensive, and last but a short period,—in consequence of their being constantly acted on by oxygen and the hydro-chloric acid of sea-water. The application of this discovery to the preservation of instruments composed of iron or steel was first suggested by Mr. Pepys; and delicate surgical instruments which would be rendered useless were their cutting parts in the slightest degree oxidized, are now kept perfectly bright by the application of zinc.

One objection has been made to the application of this principle to the preservation of the copper sheathings of ships, which is, that the copper, when effectually guarded by zinc against corrosion, becomes soon covered with marine plants and animals, which the oxide and submuriate of copper, (formed on the surface of the sheathing, previous to the application of the zinc,) completely prevented; and that the copper being rendered electro-negative by the zinc, attracts substances in the opposite state contained in the sea-water, such as lime and magnesia. But neither the marine plants and animals, nor the lime and magnesia are capable of injuring the copper; they only form a coating on the surface. When we compare the endurance of these difficulties, admitting that the above objections are well founded, with the short space of time that a copper bottom lasts, and the enormous expense of renewing the copper, they appear as nothing. Besides, it is the opinion of men of science, that by a skilful adjustment of the proportions of copper and zinc, or iron, which can be used instead of zinc on copper, these objections can be completely removed. However weighty these difficulties may be, they are confined solely to the application of zinc or iron to the copper sheathings of ships;—they are not made to the application of zinc to metallic instruments.

One more advantage, and perhaps the greatest of all, arising from this discovery of Davy's is, that iron can be used instead of copper on the bottoms of ships, thus vastly reducing the expense of sheathing. The zinc as effectually prevents any chemical action on the iron as on the copper, and hence one is as good for the purpose of sheathing as the other.

The numerous experiments which have been made by men of science since this discovery of Sir H. Davy, have fully established its value and importance, and it now remains for men to apply it to some useful purpose.

I am aware of no use having been made of this valuable discovery except in the preservation of ships' bottoms and surgical instruments; and why, I ask, do not mechanics avail themselves of its advantages? It cannot, I think, be possible for any well informed mechanic to be ignorant of any of the facts above stated. If any one is, it must be his own fault. Books are as "cheap as dirt," and if any mechanic will say he cannot buy a few books on science, and that he has no time to study books if he had them, he is poor indeed; and leads a slave's life. Such a man I sincerely pity. But what shall I say to those who *do* understand this principle—this discovery of Davy's—who do not make some application of it? Go into the workshop of the different mechanics, and see their tools undergoing constant corrosion. Go to our wharves, and see all the iron work of ships covered with rust—their anchors and chain cables covered with oxide. Go to the printing-office and see the press, red with the oxide of iron—the chases and composing sticks also covered with the same. Look at the steam engine, the most ingenious, useful, and probably the greatest of all inventions, and think whether Sir Humphrey Davy's Discovery could not be applied to that.

Wherein is the world benefitted by any discovery, if no application be made of it? To what purpose do we rack our brains in acquiring knowledge, if we make no use of it when obtained? People seem afraid to adopt any thing new. Any new invention or discovery, if it be ingenious, they view with delight; but the thought does not seem to occur to them whether it can be applied to any useful purpose; and if any one attempts the application of a new principle, be it what it may, there are thousands ready to laugh at him, as they did at Fulton, in his exertions to show to the world the use and value of that machine of all machines—the Steam Engine.

Ships are constantly building and being coppered without the least regard to this invaluable discovery; and why is it? Are shipbuilders and shipowners ignorant of the existence of this cheap and effectual preventive against the ravages of the elements, or have they tried it and found it ineffectual. If they have, I am not aware of it.

USEFUL RECEIPTS,—COMPOSITION METALS.

Common Pewter is composed of tin, lead, copper, and zinc, and is proportioned as follows.

7 lbs. of tin, 1 lb. of lead, 6 oz. copper, 2 oz. zinc.

The copper must be fuzed before the other ingredients are added;—this combination of metals will form an alloy of great durability and tenacity; also of considerable lustre.

Best Pewter, 100 lbs. tin, and 17 lbs. regulus of antimony.

Hard Pewter, 12 lbs. tin, 1 lb. regulus of antimony, and 4 oz. copper.

Common Solder, 2 lbs. of lead and 1 lb. of tin.

The lead must be melted before the tin is added; this alloy, when heated by a hot iron, and applied to the tinned iron, with powdered rosin, acts as a cement or solder; it is also used to join lead pipes, &c. &c.

Soft Solder, 2 lbs. of tin and 1 lb. of lead.

Solder for Steel Joints, 19 dwts. of fine silver, 1 dwt. of copper, and 2 dwts. of brass.

melted together, under a coat of charcoal dust; this solder possesses several advantages over the usual zinc solder, or brass, when employed in soldering cast steel, &c. as it fuzes with less heat, and its whiteness has a better appearance than brass.

Silver Solder for Jewellers, 19 dwts. of fine silver, 1 dwt. of copper, and 10 dwts. of brass.

Silver Solder for Plaiting, 10 dwts. of brass, and 1 oz. of pure silver.

Gold Solder, 12 dwts. pure gold, 2 dwts. pure silver and 4 dwts. copper.

Brass Solder for Iron.—Thin plates of brass are to be melted between the pieces that are to be joined; if the work be very fine, as when two leaves of a broken saw are to be brazed together, cover it with pulverised borax, melted with water, that it may incorporate with the brass powder, which is added to it;—the piece must be then exposed to the fire, without touching the coals and heated till the brass is seen to run.

Bronze, 7 lbs. pure copper, 3 lbs. zinc, and 2 lbs. tin.

The copper must be fuzed before the other ingredients are added;—these metals, when combined, form the bronze so much used, both in ancient and modern times, in the formation of busts, medals and statues.

A Glossary of Mechanical Terms.

Æolopile, - - A hollow metallic ball, with a small orifice, to show the power of steam.

Anneal, - - To expose Iron or any other metals to the action of fire, in order to reduce them to a greater degree of tenacity.

Arbor, - - The principal spindle or axis which communicates motion to the other parts of a machine.

Arm, - - The length of the sail of a wind mill measured from the axis.

Arms (*Axle*,) - - The two ends of an axle-tree : projecting supports in machinery.

Attraction of Cohesion, The attraction which holds the particles of matter to each other.

———*of Gravitation*, The force which causes all ponderous bodies to fall towards the earth's centre.

Automaton, - . A machine which by an internal arrangement, seems to move of itself.

Axis, - - The spindle or centre of any rotatory motion.

———*of Oscillation*, The shaft upon which any body vibrates.

———*in peritrochio*, - - One of the six mechanical powers called the wheel and axle.

———*of rotation*, The shaft round which any body revolves.

Backboards, - Boards attached to the rims of water wheels, to prevent the water from running over into the interior of the wheels.

Backlash, - - The hobbling movement of a wheel not firmly fixed on its axis.

Batter, - - A machine used early in the process of the cotton manufacture.

Bayonet, - - A piece of wood or metal with two legs to disengage and re-engage machinery.

Beats, - - The strokes made by the pallets or fangs of a spindle in clock or watch movements.

Bevel-geer, - - Wheels in which the teeth are set at angles of various degrees from the radius.

Bloom, - - A bar of iron to be passed through the rollers of an iron mill to be elongated into a bar, rod, or hoop.

Blunging, - - The act of mixing or kneading clay for the potter's use.

Brace, - - A curved instrument of iron or wood for removing small boring tools called bits.

Brake, - - A machine for separating the cuticle or outer skin from the flax plant.

Brasing, - - The soldering or joining two pieces of metal by melting of brass between the pieces to be joined.

Breast, - - The first part of a revolver carding engine.

Breasting, - - The circular sweep of Masonry, &c. which surrounds the shuttle side of a breast wheel.

Breast-plate, - - A small piece of steel with holes to receive the ends of a drill.

Breast-wheel, - - A water wheel on which water is admitted at or nearly level with the axis.

Buff-stick, - - A piece of wood covered with buff leather, used for polishing.

Bullet, - - To alter the wards of a lock in such a manner that they may be passable by more than one key.

Bush, - - A hole in the nave of a wheel.

Cœteris paribus, - - Other things being equal.

Calibre, - - The diameter of a hole.

Calk, - - To force oakum, tow, or other material in the joints of vessels, to make them steam, air, or water tight.

Camb, - - An eccentric.

Capstan, - - A vertical post resting on a pivot and turned by powerful arms or levers to raise heavy weights by crane work; a windlass.

Carbon, - - Charcoal.

Case-harden, - - The process of converting the surface of iron into steel.

Casting, - - The act of forming metal or other matter in any required shape, by pouring it into moulds while in a fluid state.

Catch, - - Various contrivances in mechanics, to act on the principle of a latch.

Cement, - - A composition for joining hard bodies.

Centre-bit, - - A boring tool in carpentry.

Centrifugal, - - Flying from the centre.

Centripetal, - - Flying to the centre.

Chafery, - - A kind of forge in the iron manufacture, where the metal is exposed to a welding heat.

Chaliometer, - - An instrument to measure heat.

Chamfer, - - A groove to receive the tenon in carpentry.

Checks, - - A term generally applied to those pieces of timber in machinery, which are double, and correspond with each other.

Chord, - - Perpendicular let fall from the radius of any circle.

Chuck, - - That part of a lathe which revolves with the arbor: to this is affixed the article to be turned.

Circumference, - - The measure round any circle.

Clack, - - A bell so contrived that it shall ring when more corn is required to be put in the mill.

Clamp, - - A pile of unburnt bricks raised for burning.

Clip, - - An arrangement to impede velocity by friction.

Clutch, - - *Vide* Bayonet.

Cackling, - - To entangle.

Cocoon, - - A small ball of silk, spun by a silk worm.

Cog, - - This word, correctly speaking, implies teeth formed of a different material to the body of the wheel, but is generally used to express all kinds of toothed wheels.

Concentric, - - Having the same centre.

Conspiring forces, - - Various forces combined into one.

Constant forces, - - Force without interruption.

Contractile forces, - - Forces which decrease.

Core, - - The internal mould which forms a hollow in foundry : as the hollow of a tube or pipe.

Countersink, - - To take off the edge round a hole to let in a screw head, that it may be even with the surface.

Couplings, - - To connect two shafts or spindles longitudinally.

Coupling-box, - - A strong piece of hollow iron to connect shafting and throw machinery in and out of geer.

Crank, - - A bent part of a shaft, by means of which a rectilinear motion is gained.

Crow-bar, - - A strong bar of iron used as a temporary lever.

Crown-wheel, - A wheel which has teeth at right angles to its radii.

Cycloid, - - A geometric curve.

Cylinder, - - A long round body ; a roller.

Dam, - - The bank or wall which pens back the water in a mill head.

Data, - - Facts from which we may deduce results.

Decimetre, - - To measure by tenths.

Dent, - - The wire staple which constitutes the tooth of a card.

Diameter, - - The line which passes through the centre of a circle.

Die, - - Pieces of steel for cutting screws, having the threads countersunk on them ; a stamp.

Doffer, - - That part of a carding machine which takes the cotton from the cylinder.

Doffing-plate, - - The plate which receives the cotton from the doffer.

Dog, - - A piece in small machinery, which acts as a pall.

Draw-plate, - - A steel plate, having a gradation of conical holes through which metals are drawn to be reduced and elongated.

Drench, - - To wet or inundate.

Drill-bow, - - A small bow moved by hand to impart motion to a drill.

Drum, - - A hollow cylinder.

Ductile, - - Malleable and soft.

Eccentric, - - Deviating from the centre, as cambs, attached to the rim or circumference of a shaft for lifting forge hammers, stampers, &c.

Effectvie-head, - - The real head, or that which can be applied to practice.

Effluent, - - Flowing from; running out.

Efflux, - - The act of flowing out.

Epicycloid, - - The curve described in the air by a point on the circumference of a circle, when this circle rolls on another circle at its base.

Equilibrium, - - That peculiar state of rest in which a body is maintained by the force of gravitation, when the quantity of matter in it is exactly equal on each side of the bar or point, on which it is supported.

Escapement, - - That part of a clock or watch movement which receives the force of the spring or weight, to give motion to the pendulum or balance.

Face of the tooth, - The curved part of a tooth which imparts impulse to another wheel.

Faggot, - - Pieces of iron bound together for remanufacture.

Fan, - - Small vanes or sails to receive the impulse of the wind, and by a connection with machinery, to keep the large sails of a smock windmill always in the direction of the wind · an instrument to winnow corn; also to decrease speed by its action on the air.

Female screw, - The spiral threaded cavity in which a screw acts.

File, - - A tool used by smiths for the abrasion of metals; denominated, according to its fineness, rough, bastard, or smooth.

First mover, Power, either natural or artificial·

Flanch, - - An edge or projection for the better connection of piping or castings of any description.

Flank of the tooth, The straight part of a tooth which receives impulse from another wheel.

Float, - - The board which receives the impulse of the water either in breast or undershot wheels.

Floodgate, A strong framing of timber to pen back or let out water.

Flux, - - Ingredients put into a smelting furnace to fuse the ore of metals.

Fly wheel, A heavy wheel to maintain equable motion.

Foot brake, - A machine used in the flax manufacture.

Forge, - - A manufactory in which metals are made malleable;—a furnace.

Forge, - - To form by the hammer.

Friction, - - Inequality of surface; act of rubbing together.

Frisket, - - An iron frame used in printing to keep the sheet of paper on the tympan, and to prevent the margin from being blacked.

Fulcrum, - - The point or bar on which a lever rests.

Geering, - - Part of mill work.

Gibbet, - - That part of a crane which sustains the weight of goods.

Gig mill, - - A mill in which the nap of woolen cloth is raised by the application of machinery.

Girder, - - The largest timber in a floor.

Girt, - - *Vide* Gripe.

Gravity, - - Tendency towards the centre of the earth : weight.

Gripe, - - A pliable lever which can be pressed against a wheel to retard or stop its motion by friction.

Governor, - - A pair of heavy balls connected with machinery to regulate the speed on the principle of centripetal force.

Gudgeon, - - The centres or pivots of a water wheel.

Half stuff, This term, in general, implies any thing half formed in the process of manufacture.

Heald or Heddle, *Vide* Heddle.

Heckle, - - A metal comb for the manufacture of flax.

Heddle, - - That portion of a loom which imparts motion to the warp of a web during the process of manufacture.

Helve, - - The shaft of a forge or tilt hammer.

Hopper, - - A tunnel in which grain is deposited, whence it runs between the stones of a flour mill.

Horology, - - The art of constructing machines for measuring time.

Hydraulics, - - The science which treats of the motions of fluids, of the resistance which they oppose to moving bodies, and of the various machines in which fluids are the principal agent.

Hydrodynamics, The science which embraces the phenomena exhibited by water and other fluids, whether they be at rest or in motion : it is generally divided into two heads, hydrostatics and hydraulics.

Hydrostatics, The science which considers tne pressure, equilibrium, and cohesion of fluids.

Impact, - - Transmission of force.

Impinge, - - To dash against.

Inertia, - - That tendency which every piece of matter has, when at rest, to remain at rest ; and when in motion to continue that motion.

In Vacuo, Empty space, void.

Isochronal, Of equal duration.

Isochronous, The vibrations of a pendulum.

Jenney, - - A machine used in the process of the cotton manufacture.

Jib, - - *Vide* Gibbet.

Kiln, - - A place where bricks are burnt.

Kink or Kinkle, The entangling of cordage from overtwisting.

Lateral, - - A horizontal or lengthwise movement.

Lathe, - - A machine used by turners.

Lantern,	A wheel with staff teeth ; the trundle or wallower.
Leaves,	The teeth of a pinion.
Lever,	One of the mechanical powers.
Line of centres,	A line drawn from the centre of one wheel to the centre of another, when their circumferences touch each other.
Locomotive,	The power of changing place.
Loom,	A machine used by weavers in the making of cloth.
Machinist,	One who makes machines.
Mandrel,	Part of a lathe ; cone used by smiths ; a cylindrical piece of polished iron or steel put down the bore or hole of a pipe during the process of elongation.
Mastering,	Preparation of lime used by tanners.
Matrice,	The concave form of a letter in which the types are cast.
Maximum,	Is the utmost extent of any movement or power.
Mechanist,	One acquainted with the laws of mechanics.
Mill head,	The head of water which is to turn a mill.
Mill tail,	The water which has passed through the wheel race ; or is below the mill.
Minimum,	The reverse of maximum.
Momentum,	The force possessed by matter in motion.
Monkey,	A weight or mass of iron let fall from a height to drive piles into the earth.
Mortise,	A joint.
Movement,	The working part of a watch or clock.
Nave,	The centre, or that part of a wheel in which the spokes or arms are fixed.
Nealing,	*Vide* Annealing.
Nippers,	Pincers with cutting edges for dividing metals.
Nitric acid,	A corrosive acid extracted from nitre.
Ouse,	Preparation of bark used by tanners.
Overshot wheel,	A wheel which receives the water in buckets at not more than 45 degrees from the apex.
Oxyd,	A combination of oxygen with a metallic or other base.
Oxygen,	A gas which supports combustion.
Paddle,	A kind of oar ; floats to a wheel.
Pall,	A small piece of metal which falls between the teeth of a ratchet wheel, to prevent a load which has been raised from descending when the operative power is removed.
Pallet,	That part of a watch or clock escapement on which the crown wheel strikes.
Pendulum,	A weight suspended by a flexible cord to an axis, so as to swing backwards and forwards, when once raised by the force of gravitation.
Periphery,	The circumference of a wheel.
Perpendicular,	At right angles to a given base.

Pick, - - A chissel for dressing the stones of a flour mill.

Pile, - - A large piece of timber, pointed at one end, to drive into the earth to sustain the piers of bridges, &c.

Pin, - - To strike a piece of metal with the narrow end of a hammer to form dents and produce elongation.

Pincers, - - A tool formed by placing two levers on one fulcrum, regulated by a screw movement, for holding bodies firmly.

Pinion, - - A small toothed wheel.

Pirn, - - The wound yarn that is on a weaver's shuttle.

Piston, - - A plug made to fit tight and work up and down a cylinder in hydraulic engines.

Pitch lines, The touching circumferences of two wheels, which are to act on each other.

Pitch of the wheel, The distance from the centres of two teeth, measured upon their pitch line.

Pivot, - - A short shaft on which a body turns or vibrates.

Platina, - - A white metal capable of withstanding great heats.

Pliers, - - A small tool constructed similarly to pincers.

Plumb, - - A leaden weight suspended by a cord to ascertain the perpendicular.

Plunger, - - A body that is forced into a fluid in hydraulic engines, to displace its own weight.

Portable steam engine, A steam engine built in a compact form, and not attached to the wall of the building in which it works.

Proportional circles, *Vide* Pitch lines.

Proportional radii, The radii of two circles whose circumferences are in contact.

Puddling, - - The act of ramming with clay to arrest the progress of water.

Puddling furnace, A furnace used in the iron manufactures.

Pulley, - - A small wheel over which a strap is passed.

Quintal, - - A French or Spanish weight equivalent to 100 lbs. of those respective nations.

Rabbit or Rap-it, The strong wooden spring against which the forge hammer strikes on its ascent.

Race, - - The canal along which the water is conveyed to and from a water wheel.

Rack, - - A straight bar which has teeth similar to those on a toothed wheel.

Radii, - - The plural of radius.

Radius, - - The semi diameter of a circle; the arm or spoke of a wheel.

Rasp, - - A species of file, on which the cutting prominences are distinct, being raised by a point instead of an edge.

Rasure, - - The act of scraping.

Ratch, - - A bar containing teeth into which the pall drops to prevent machines running back.

Ratchet wheel, A wheel having teeth similar to those of a ratch.

Reciprocating, Acting alternately.

Rectilinear or Rectilineal, Consisting of right lines.

Reed, - - Part of a loom resembling a comb for dividing the warp.

Regulator, – A small lever in watch work, which, by being moved, increases or decreases the amount of the balance spring that is allowed to act.

Reel, - - A frame on which yarn may be wound.

Reeling, - - The act of winding yarn on a reel.

Reservoir, - - A large basin or conservatory of water.

Reverberatory, Beating back.

Reverberatory furnace, A furnace used in the iron and copper manufactures.

Rivet, - - To form a head by the percussion of a hammer, to prevent a piece of metal which has been passed through an orifice, to connect things together, from returning.

Roller gin, - A machine to divest cotton of the husk and other superfluous parts, previous to the commencement of the manufacture.

Rotatory, - - Revolving.

Rowans, - - Cotton in that part of the manufacture before it goes to the roving frame.

Rubber, - - A heavy file used for coarse work.

Rubble, - - A mode of building.

Rynd, - - The piece of iron that goes across the hole in an upper mill stone.

Safety valve, - A valve which fits on the boiler of a steam engine to guard against accidents by the steam obtaining too high a pressure.

Saw gin, - - A machine on the principle of the roller gin.

Scantling, - - The length, breadth, and thickness of any solid body, taken lineally.

Scapement, - - *Vide* Escapement.

Scotching, - - The operation of packing hemp before it goes to the market.

Scoria, - - Slag from a smelting furnace.

Scowering Barrel, An octagonal, or other shaped barrel, in which scrap iron, &c. is cleansed from rust by friction as it revolves.

Scrap iron, - - Various pieces of old iron to be remanufactured.

Screw, - - One of the mechanical powers.

Scribbler Engine, An engine used in the process of the cotton manufacture.

Shaft, - - A long piece of wood or metal, on which large wheels are fixed in mill work.

Sheeve, - - A small kind of pulley.

Shoulder, - - A support by means of a projection from a surface.

Shrouding, - - The boards, &c. which form buckets of water-wheels.

Shuttle, - - An arrangement to allow or shut off water from a water wheel ; a small piece of wood which carries the thread in weaving.

Size, - - Gelatinous matter made from animal or vegetable substances, and applied to fibrous materials to impart stiffness.

Slag, - - Scoria, or refuse from an iron furnace.

Sledge hammer, A heavy hammer, used by a smith with both hands.

Slip, - - Potter's clay of the requisite consistency.

Sluice, - - Vent for water ; a kind of flood gate.

Snail movement, An eccentric.

Solder, - - Various compounds of metals for conjoining other metals, that are less fusible than such compound.

Sparable, - - From sparrow bill, small nails to drive into shoes

Spindle, - - A thin piece of wood or steel on which yarn is wound after it has been twisted ; a small kind of shaft.

Spokes, - - The radial piece which connects the periphery of a wheel with its centre piece or nave : this term is only applied to carriages.

Spatula, - - A thin knife, used mostly to extend superficially some semi fluid matter.

Spring, - - An elastic body formed of metal or wood.

Spring arbor, - The arbor or spring round which the main spring of a watch is wound.

Spring box, - The box which contains the main spring.

Spur geer, - - Wheels whose axes are parallel to each other.

Splice, - - To conjoin lengthwise two flexible pieces ; by the interposition of their respective parts, so as to maintain them in conjunction by friction.

Staff, - - The teeth of a trundle, lantern, or wallower.

Staking on, - To drive wedges into the bush of a wheel or pulley, to fix it firm on a shaft or spindle.

Start or Strut, The partitions which determine the form of a bucket in an over shot wheel ; the shoulder or wrest.

Staves, - - The plural of staff.

Steam boat, - - A boat moved by steam power.

Steam engine, A machine for applying the force of steam to create motion.

Steel yard, - - A machine which denotes the weight of bodies, by placing them at different distances from its fulcrum.

Stereotype, - - The art of casting solid plates from moveable types, to print from.

Strike, - - A thing used to strike any thing level in a measure :—the strickle.

Strata, - - The plural of stratum.
Stratum, - - A single layer or bed of any one thing.
Swag, - - An unequal or hobbling motion.
Swifts, - - The rapid movement in a carding machine.
Swingling, - - *Vide* Scotching.
Swing tree, - - Any beam that vibrates.
Swivel, - - A thing fixed in another body to turn round upon.
Syphon, - - A bent tube with unequal legs through which a fluid will flow by the force of gravity.
Tail Water, - Water which impedes the water wheel in mill work.
Tank, - - Reservoir for water, &c.
Teasles, - - Thistles used to raise the nap of cloth in the gig mill.
Tenon, - - That part which fills up the mortise.
Tilt hammer, - - A hammer lifted by machinery, to forge iron or steel.
Treadle, - - A lever affixed to a crank which communicates motion to machinery by a foot movement.
Throwsting, - - Spinning.
Triblet, - - *Vide* Mandrel.
Truckles, - - Small rollers for diminishing friction.
Trundle, - - A small wheel with staff teeth ; the lantern, or wallower.
Tuyere or Tue iron, An orifice through which a blast or strong current of air is passed into forges.
Tympan, - - That part of a printing press on which the paper is laid to receive the impression.
Undershot wheel, A wheel acted on by water below its centre.
Vacuum, - - Void of air.
Valve, - - A cover to an aperture, in hydraulic machines, to prevent fluids from taking a wrong course.
Vane, - - A flat surface capable of being moved by the current of a fluid ; as, for instance, the vanes of a windmill, moved by the wind.
Tappets, - - Projections on the plug tree of a steam engine which open and shut the valves at proper intervals.
Varnish, - - A solution of certain resinous bodies in spirits or oils, which assumes a solid form on dissication..
Velocity, - - The measure of quickness with which a body moves;
Vertical, - - Perpendicular to the horizon.
Vibration, - - Rapid alternating motion.
Virtual head, - - The real or effective head.
Vis inertia, - - *Vide* Inertia.
Wabble, - - A hobbling unequal motion.
Wallower, - - Small wheel with staff teeth ; the trundle or lantern
Warp, - - The layer of threads which extends the length of the piece to be woven.
Wheel race, - - The place in which a water wheel is fixed.

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*For explanation of Tables No. 1 and 2, see 15th, 16th and 17th pages.